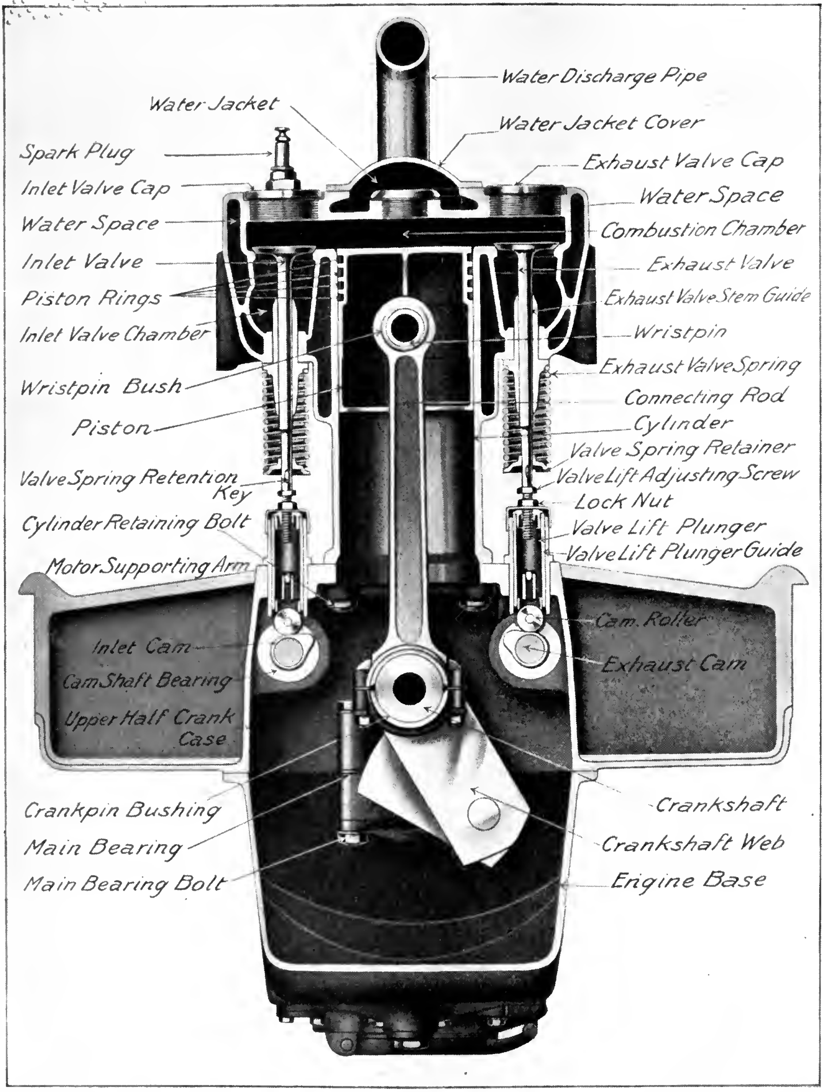

End Sectional View of Typical Internal Combustion Motor. The Prime Mover that Made the Automobile, Motorcycle, Aeroplane, and Motor Boat Possible.

THE MODERN GASOLINE AUTOMOBILE

ITS DESIGN, CONSTRUCTION MAINTENANCE AND REPAIR

A PRACTICAL, COMPREHENSIVE TREATISE DEFINING ALL PRINCIPLES PERTAINING TO

GASOLINE AUTOMOBILES AND THEIR COMPONENT PARTS

THE MOST COMPLETE AND UP-TO-DATE EXPOSITION ON GASOLINE AUTOMOBILES EVER PUBLISHED

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BY VICTOR W. PAGÉ, M.E.
LATE TECHNICAL EDITOR OF "THE AUTOMOBILE JOURNAL"

Illustrated by 500 Specially Made Detailed Illustrations and Diagrams

THE ILLUSTRATIONS DEFINING CONSTRUCTION OF PARTS ARE MADE FROM ACCURATE ENGINEERING DRAWINGS ACCORDING TO BEST AUTOMOBILE ENGINEERING PRACTICE

NEW YORK
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FIRST IMPRESSION

COMPOSITION, ELECTROTYPING AND PRESSWORK
THE TROW PRESS, NEW YORK, U. S. A.

TO MY UNCLE

ERNEST F. McCARTHY

A PIONEER AUTOMOBILE DESIGNER AND CONSTRUCTOR

THIS TREATISE IS INSCRIBED

IN GRATEFUL APPRECIATION OF PRACTICAL AID

AND MECHANICAL INSTRUCTION

GIVEN AT A TIME IT WAS MOST NEEDED

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GENERAL INTRODUCTION

The modern motor car has reached that period in its development where one can safely say that it has become perfected to such an extent that further improvements must be in matters of detail only and not in alterations of essential components. It has been so widely adopted and is used in so many industrial applications that even the most conservative must admit the automobile has ceased to be an experiment and it is a reliable method of transportation that has demonstrated its worth conclusively.

It is said that there are over 800,000 motor vehicles in use in the leading countries of the world, and the yearly output of the world's manufactures is approximated at about 300,000 cars per annum. Of this number over 500,000 power-propelled vehicles are used in the United States, and the yearly output of domestic producers is estimated at 190,000 automobiles. The enormous demand existing for this practical conveyance has impelled the manufacture of well-developed types of motor cars which can be sold at very moderate prices because they are produced in large numbers. This has resulted in a wide increase in the number of motorists and many who formerly could not afford the higher priced automobiles have become motor car operators because they can maintain the moderate priced cars at present obtainable without too great expense.

Obviously, it is not difficult to acquire a knowledge of the principles of operation or the mechanism of the conventional motor car if one has had mechanical training or a practical knowledge of automobile construction, and it is patent that many motorists who are driving their own cars have but a vague understanding of the principles of operation of the mechanism which comprises the up-to-date automobile. The ranks of motorists might be augmented by many who have the means to purchase but who believe that the maintenance cost would exceed that of a horse-drawn conveyance of equal capacity, and the natural impression which prevails that only those well versed mechanically can operate motor cars successfully can be dispelled only by a better understanding of motor car construction. When one takes cognizance of the many vehicles successfully operated by comparatively inexperienced persons it is apparent that operating is not difficult, but it is the repairing and maintenance costs that deter many from owning motor cars.

There has been no lack of instruction books or elementary treatise dealing with motor vehicle construction, maintenance or operation, but in these, for the most part, a common error has been made of assuming that the reader had more or less knowledge of mechanics. It is evident that any work which presupposes a certain amount of training on the part of the reader cannot be successfully employed in teaching the rudiments of any science. At the other hand, pamphlets which are too elementary in character cannot convey a practical working knowledge because so much is left for the motorist to learn after he has grasped the main principles underlying the design. Many business or professional men do not possess even an elementary knowledge of mechanical principles, and as this class forms the largest proportion of the motoring element, in defining the basic principles of an automobile, it is necessary to use simple exposition that oftentimes appears to be elementary to the student or engineer well versed in the subject under discussion.

Many of the works on automobile construction which have been exceptionally valuable in the past have a materially lessened value because much of the matter contained therein is out of date and not applicable to the vehicles of the present day. In the present work the writer will endeavor to define the essential elements of the modern gasoline motor car, and after explaining the basic principles upon which the successful use depends, it is proposed to describe actual forms and typical mechanisms so that their practical application and the relation the various parts bear to each other can be easily understood. It is obvious that familiarity with the machinery of an automobile will enable the operator to give intelligent attention which will insure the longest life and minimum operating expense.

It is believed that a systematic and logical arrangement of the subject will enable the reader to gain an understanding of the functions of each part and the typical groups of mechanism illustrated and described should make for a better understanding of the various parts as they actually are in the leading automobiles. While it has been the practice in works of this character to include a general exposition of all types of self-propelled conveyances, including gasoline, steam, and electric automobiles, in the present instance, matter relating to the steam or electric motor car will not be given. The writer will discuss only those automobiles in which the gasoline engine or hydro-carbon motor is utilized as a prime mover.

The gasoline car is now used almost universally, and the steam vehicle or conveyance propelled by electric power has been practically relegated to the background. The gasoline car has such obvious advantages and is so economical to maintain that when a proper analysis of its good features is made, the reason for its popularity will be apparent. Among many of the advantages of the gasoline car may be mentioned first—the large range of choice because of the number of types available on the market. Second—the capability of running long distances without replenishing supplies. Third—wide dissemination of knowledge regarding its construction. Fourth—no gauges to watch and practically automatic operation. Disadvantages sometimes cited are an occasional unpleasant exhaust, the necessity for physical starting of the engine (at the present time largely eliminated by self-starting mechanisms), and shifting change speed gearing when road conditions or gradients demand maximum engine power.

The steam car still has a number of staunch adherents because it possesses important advantages in that it has a good range of power which can be easily controlled, it is quiet in action, has freedom from vibration and simple means for control and easy restarting after a temporary stop. Some of the factors which militate against its use are a limited number of makes to select from, attention and time required to get the vehicle started after a stop of some moment, close attention required to steam, air, water, and other indicators, and on cold or damp days a visible exhaust due to the condensation of the used steam discharged from the engine.

The electric car has many good features, and it is widely used for both pleasure and business purposes wherever proper charging facilities are available. It is quiet, clean, easily started and controlled, runs with no appreciable vibration, and has very simple and efficient gearing. The disadvantages, however, counterbalance the good points. Such vehicles are expensive to operate, owing to the great weight to be driven. Their touring radius is limited, the average being from twenty to fifty miles per charge of batteries. Other factors are the great weight to horse power ratio due to the use of storage batteries; the time taken to recharge; the liability of batteries to injury, a high initial and maintenance cost and slow speed. It is apparent that its chief field of activity would be in towns or cities, delivering merchandise, making professional or social calls, attending theaters, shopping, and other strictly urban work. Obviously, it cannot be used for touring purposes, but where cost is not an all-important element one will find the electric automobile entirely suitable and practical for all town work.

The writer believes that neither the steam nor electric automobile is of sufficient moment at the present time, when compared to the number of gasoline automobiles in use, to warrant an extended discussion of their construction or operation. In the present volume the space which in contemporary works is usually devoted to these types will be utilized in a practical discussion of items which are usually neglected, such as gas engine operation, maintenance and repair; hints relating to tire restoration or manipulation and an exposition of the latest and most suitable accessories which conduce to greater safety or comfort while motoring.

The omission of the historical matter which usually prefaces a work of this character may be criticized as well as the elimination of many machine details that are commonly presented chiefly because of their value in showing progress made. As the science of automobile engineering has reached that point where radical departures from the conventional or standard construction are not considered with favor, it is safe to assume that the era of standardization and stability of design is at hand. Many changes have been made in the past in basic design of vehicles or their components, and many parts formerly thought essential can be dispensed with. As an example of the discarding of designs which gave promise of being permanent, one may mention the practical elimination of the high-wheeled or buggy-type automobile, which are now almost entirely off the market.

One-, two-, and three-cylinder four-cycle engines and those of the compound form or having horizontal cylinders have been displaced by the modern four and six vertical cylinder forms, the former being used even in the cheapest types which formerly utilized one or two cylinder power plants. Simple air-cooling systems are seldom used, and angle iron or wood frames which were supplied on many pleasure cars are now used solely on heavy commercial vehicles and pressed steel frames are now almost universally used in pleasure cars. Plain bearings, used in the past in gear sets and axles, have been replaced by anti-friction members. Lever, tiller or rack and pinion steering gears are seldom used now, irreversible wheel types are employed on nearly all classes of cars except some electric runabouts. The single chain drive is seldom seen, while the double chain system of power transmission which had wide application in pleasure cars has been succeeded by more efficient driving systems and is used only in heavy commercial car work by modern engineers.

Low tension ignition and the use of batteries for electric current production are found only on old type cars. All modern vehicles include mechanical generators of electricity such as the magneto, or dynamo. Two-cycle engines are not widely used except in marine applications. Short stroke high-speed motors have been replaced by the more efficient and enduring modern moderate speed forms. Expanding band clutches which had a number of advocates in the past are seldom used at the present time. But few makers use planetary or individual clutch transmissions, and two speed gearsets are seldom seen except when an epicyclic change speed gear is fitted.

The progressive sliding gear type is passé, and the friction transmissions which were formerly employed in many forms are now utilized only in the simplest design on a few cars. It was formerly considered good practice to use engines fitted with automatic speed governors as automobile power plants, but governed engines are now found mainly on motor trucks. Wick, surface, drip, bubbling, film or generator valve type carburetors or vaporizers have been entirely replaced by the float feed spraying type. Among some of the other features of construction which are in decline may be mentioned tubular front axles, semi-elliptic rear springs or long side springs and driving axles without torque or radius members.

On the other hand, during the past year there have been a number of innovations which merit detailed description because they are found on many automobiles of late models. Other works dealing with automobile construction published in the past, make no reference to these improvements owing to their recent development. Among these may be mentioned torpedo and other symmetrical body forms designed to overcome air resistance; sleeve valve motors, a general adoption of the selective sliding gearset in the three and four speed forms, the adoption of shaft and bevel gear drive on even the heaviest pleasure vehicles, the increasing tendency to favor worm gear power transmission, the universal application of magneto ignition and development of electric lighting systems.

There is also more consideration of left hand control, growing use of unit power plants, wider application of block motors and two bearing crank shafts, and a better appreciation of the advantages of the underslung chassis. The I-beam section front axle is almost universally used, and there is marked improvement in multiple disc clutches, wider application of practical self-starters, and more general adoption of ball and roller bearings at all points. The use of long stroke motors, offset cylinders and automatic lubrication systems make for pronounced increase in automobile efficiency. There is also an augmenting tendency to place change speed gearing on the rear axle, toward the use of three-quarter springs for rear suspension, supplying larger wheels and tires as well as quick detachable wheels and rims. Some of the foreign tendencies which may influence domestic design are a return to wire wheels by some of the leading European engineers; the application of silent chains for valve operation, in change speed gearing and even final drive and use of front wheel brakes.

In addition to these final improvements may be added a better realization of the advantages of alloy steels, a universal tendency to weight reduction, and increase of power to weight ratio. The floating rear axle has almost entirely displaced the simpler form and marked improvement is noticed in carburetor construction owing to changes in grade of fuel now supplied which impelled the development of multiple jet and compensating vaporizer forms. Many novel and practical accessories have also been developed.

In order to make this work wide in scope, not only will principles of construction and operation be discussed comprehensively, but many examples from contemporary foreign and domestic practice will be given to amplify the subject and increase the reader's opportunity for the acquirement of a practical motoring education. The illustrations have been carefully prepared, and for the most part the cuts detailing construction of the various components are reproduced or adapted from actual working drawings and thus are true outline representations of the objects described. As previously stated, it is believed that a concentration of effort in treating exclusively of vehicles propelled by internal combustion motors will make this treatise one of more practical value to the majority of motorists than any heretofore published.

The repair hints and suggestions given for maintenance and equipment are based on a wide practical experience which dates since the inception of the industry as a designer, repairer, and operator of motor vehicles, and should be of exceptional value to those who have not had an opportunity to become familiar with automobiles but who can apply the experience of others to good advantage.

THE AUTHOR.

THE
MODERN GASOLINE AUTOMOBILE

CHAPTER I

Defining Trend of Modern Practice—Explaining Important Components of the Motor Car and Considering Functions of Each Group of Mechanism.

DURING the past decade great progress has been made in all branches of engineering and science. This is especially true in mechanics, and one of the most notable achievements has been the advancement of the self-propelled vehicle from a crude and unsatisfactory construction to one of great refinement and practicability. In ten years the growth of the automobile industry stands unparalleled in the industrial history of the world. One familiar with the improvement of the motor conveyance during that time and who remembers the early types marvels at the refinement of detail and the changes in design which exist in the vehicles of the present day. The modern gasoline automobile fills every need as it is comparatively light, powerful enough for all road conditions, easily controlled and capable of running for thousands of miles without adjustment of the mechanism. It surpasses the powerful locomotive in speed and reliability, and has a radius of travel greater than any other conveyance.

There are numerous standard principles upon which motor-car construction is based, and some of these differ from each other radically, both in theory and practice. Many constructions, if looked at from a purely academic point of view, will appear to possess advantages which cannot be questioned, though on further consideration a car of apparently inferior design which does not have the same method of accomplishing a like object may be a better seller and a more popular car among motorists.

The tendency of the motor-car designer of the present day is toward simplicity and increasing efficiency of the mechanism. There are many rules of practice leading to this end generally known to engineers, though not accepted by all as the best methods of construction for motor vehicles. It is the writer's purpose to review all the types of the various automobile components that have merit, and the qualities of each design will be given as stated by those favoring it. This is not intended as a criticism, but to enable the motorist not informed regarding details of motor-car building to make intelligent comparison with other forms.

Within the last few years the design of automobiles has been considerably changed, and the difficulties that previously retarded development have been for the most part eliminated by modern automobile engineers. This gradual modification of the automobile from a crude mechanism to a practical product has been attained without radical changes that many confidently forecasted at the inception of the industry. The essential elements of the motor car of to-day remain practically the same as far as basic principles of design are concerned, as those which formed the basis of the first motor car. Only the details have been changed and the forms which have resulted from the gradual process of evolution show a steady tendency toward uniformity of design.

Important Components of Modern Motor Cars.—In this era of progress, one would hesitate to assert that the motor car had been perfected or that it had reached a finality in design, though the experience of the last few years would justify one in assuming that the principles of construction now applied so successfully may reasonably be considered permanent. The elements which have been proven essential to insure successful operation of all self-propelled conveyances may be easily defined as follows:

First: The endeavor of modern constructors is to make all operating parts of such material, size, and strength, that the severe strains imposed by the rough nature of the average road surface will be resisted adequately and to secure endurance and serviceability under all possible conditions of operation.

Second: The mechanism should be as simple as it is possible to make it, as this promotes ease of repairing, facility in handling, and lessens the liability of trouble by reducing complications. The parts should be in proper proportion and arranged in such a manner relative to each other that one may be removed or replaced without disturbing other correlated appliances.

Third: The power furnished by the gasoline motor carried in the frame must be transmitted to the traction wheels or to the revolving shafts to which they are fastened with as little friction and power loss as is possible.

Fourth: The two driven wheels (preferably the rear ones) must be connected to some form of compensating or balance gear which enables each wheel to revolve independently of the other at times and at different velocities, because in turning corners the outer wheel describes a larger arc and consequently a longer path than the inner member. The differential gear was one of the most important elements which made for the successful development of the automobile.

Fifth: The steering should be done by the two front wheels which are carried at the ends of a yoke axle which is securely fastened to the chassis frame by means of the springs. The wheels are carried on steering knuckles which must be arranged to assume different angles when the vehicle is turning corners or deviates from a straight path in order to secure positive steering.

Sixth: Springs must be provided, which will have sufficient strength and elasticity to neutralize vibration and allow for unevenness of the road surface by their yielding qualities and thus reduce body movement. In order to relieve the machinery, running gear and passengers of the inevitable vibration which obtains at even moderate speed on ordinary roads the wheels should be provided with very resilient tires, preferably of the pneumatic or inflated forms for pleasure cars, and cushion or solid rubber on the heavier and slower moving motor trucks.

Seventh: The gas supply to the motor, the ignition of the charge, and the continuation of the engine cycle of operations should be automatic and require no attention from the operator after the motor is once started. To secure continued operation, mechanical means must be provided for constant lubrication of all moving parts. All components which have movement relative to other parts should move with as little power loss by friction as possible, in order to conserve the available motor energy for tractive purposes. Anti-friction bearings of the ball or roller type should be employed on all rotating shafts in the power plant, transmission system, and in the wheels to save power.

Eighth: The center of gravity must be carried relatively low, which involves placing the body as close to the ground as practical considerations will permit. The wheel base, which is the distance between front and rear wheel centers, should be long, in order to secure the best result in tractive effort, steering, and comfortable riding. The power plant and other essential mechanism should be carried on a frame which will be supported in such a manner that road shocks will not be transmitted to them and so coupled together that no frame distortion will produce disalignment of the driving shafts.

Ninth: The control elements must be designed with a view to easy handling. This means that the steering gear should be irreversible—i. e., the hand wheel should not be affected by side movement of the front wheels, thus relieving the driver's arms of all undue strain while driving. Motor regulation should be by levers placed convenient to the driver's hands or feet, and gear shifting should be accomplished without difficulty. Powerful brakes must be employed to insure positive check of vehicle motion whenever it is desired to bring the conveyance to a stop. It is evident that the levers through which the brakes are operated should be so proportioned that a minimum of effort on the part of the operator will serve to check the vehicle immediately.

Division of Motor-Car Mechanism in Groups.—In order to deal systematically with the subject of motor-car construction, one may divide the essential mechanism into groups and treat each of these assemblies in detail. In order to understand the functions of the various parts, views of typical pleasure and commercial car chassis, with all components clearly indicated are presented in Figs. 1 to 7. These show conventional arrangements of parts in vehicles which are adapted to a wide range or work. Of the many elements comprising the automobile, the source of power is the most important. Then comes the method of power transmission, and last the various chassis parts which have to do with suspension, control, etc.

By referring to illustrations, which show the construction of typical gasoline car chassis so clearly, the functions of the various parts and their relation may be easily understood. The basis of any conveyance, whether animal drawn or power propelled, is a running gear. This consists of a frame supported on springs which rest on the axles, which in turn carry the wheels on which the whole assembly can roll over the ground. In the horse-drawn carriage where there is no necessity for a heavy or strong supporting frame, because of the light weight of the body it is possible to attach the springs directly to the sills on which the body rests. In a motor vehicle, however, the frame is usually separate from the carriage work, because it is often necessary to remove the body to gain access to some portion of the mechanism which may need attention. The frame of an automobile must be strong, because the engine and parts of the transmission system are installed thereon, and also because the speed possibilities of the automobile make it necessary that the frame be of sufficient strength to resist the stresses due to car movement when driven over uneven road surfaces. These strains are not present in other forms of conveyances. The locomotive which is capable of high speed and which is very heavy, travels on a smooth track, while ordinary horse-drawn carriages are not affected materially by the roughness of the path on which they travel because of their low speed and light weight. In the frame, or chassis group, one may include the main frame, subframe, steering gear, clutch and brake pedals, hand levers for varying change speed gear ratios, and applying emergency brakes; the front axle and its steering connections, the driving axle and brakes, the wheels, the tires, and the springs which form a yielding connection between the axles and the frame.

The power plant of a gasoline automobile is composed of a number of distinct devices of which the engine proper is the most important, though all of them are necessary to insure practical operation. In order to describe power plant construction logically, it may be divided into six distinct assemblies, each of which may be resolved into the various parts of which they are composed. The most important assembly is the motor; then the gas-supply system, the ignition apparatus, the devices used for lubrication, the system of cooling, and the muffler assembly.

The power transmission mechanism is the next group of importance. In this assembly one places the clutch, the gearset, the driving means, and, in most instances, the rear axle and traction members.

Arrangement of Parts Varies.—In the conventional car the motor is usually placed at the front end of the frame, and the various auxiliary devices are grouped around it. This is the modern method of power plant placing, but even now there are cars constructed in which a horizontal engine is placed longitudinally in the frame parallel with the side members. This arrangement was formerly more popular than it is at present, because it permitted a simple method of power transmission by use of single driving chain. In some cars the change speed gearing is placed in the center of the frame, or directly back of the engine, as shown at Fig. 1. In other cars it may be incorporated with the rear axle, as outlined in Fig. 2. The final drive to the rear wheels may be by means of shaft and universal joint connection, as shown at Figs. 1 and 2; this being the common arrangement on pleasure cars; or by means of a combination of shaft and chains used more often on commercial vehicles. This form of drive is shown at Figs. 4, 5, and 6. The power delivered by the motor crank shaft is transmitted to a countershaft which is placed across the frame by means of a shaft, and from each end of these countershafts the energy is delivered to the rear wheels by chain and sprocket connection.

There are many other variations in arrangement of parts which will be described in proper sequence. The examples mentioned are given merely to show that the essential elements may be placed at various points in the frame without impairing their utility. The complete frame assembly, including power plant and exclusive of the body or other carriage work, is usually termed a "chassis." There is no marked difference between pleasure or commercial vehicle construction. The same essential elements are incorporated in both, though obviously the parts of a conveyance intended for industrial transportation are made much heavier because of the severer duties they perform than those employed in pleasure cars which, nevertheless, may have much greater power.

Parts of Typical Automobiles and Their Functions.—A brief explanation of the function of each part of the gasoline car chassis depicted at Fig. 1 will serve to afford a better understanding of the construction of an automobile. The purpose of the front axle is not unlike that of a horse-drawn vehicle, but it is much different in construction. The wheels are installed on movable spindles, or steering knuckles, which are supported by yokes permitting one to move the wheels for steering rather than turning the entire axle on a fifth wheel, or jack-bolt arrangement, as in a horse-drawn vehicle. This axle is attached to the frame by spring members which allow a certain degree of movement without producing corresponding motion of the frame.

The radiator, which is placed directly over the axle in front of the motor, is employed to hold the water used in keeping the engine cool and is an important part of the heat-radiating system. The starting handle is a crank by which the motor crank shaft is given sufficient initial movement by the operator to carry the engine parts through one or more portions of the cycle of operations, this starting the engine. The tiebar joins the arms of the steering spindles on which the wheels revolve, and insures that these will swing together and in the same direction, either to the right or left. The steering link, often called the "drag link," connects one of the steering knuckles of the front axle with the steering gear.

The motor may be one of the many forms to be described and one of two distinct types. The dash is a wooden or metal partition placed back of the power plant to separate the engine from the seating compartment. It is often employed to support some of the auxiliary apparatus necessary to motor action or some of the control elements. The clutch is a device operated by a pedal, which permits the motor power to be coupled to the gearset and from thence to the driving wheels, or interrupted at the will of the operator. It is used in starting and stopping the car and whenever the change speed gears are shifted. The accelerator is a small pedal which actuates a valve on the gas-supply device to permit more explosive mixture being fed to the engine when it is desired to increase the motor speed. Its function is comparable to that of the throttle of a steam engine. The pedals are foot-operated levers; one of which releases the clutch, the other applies the running brakes. The motor control levers on the steering column are used in conjunction with the accelerator to vary the rotative speed of the motor and thus regulate the energy produced in proportion to the work to be performed. The emergency brake lever applies a powerful braking effect when it is desired to stop the car quickly and also when one wishes to lock the brakes if car movement is arrested on a down grade. The change speed lever operates the sliding gearing, which is utilized to produce varying ratios of velocity

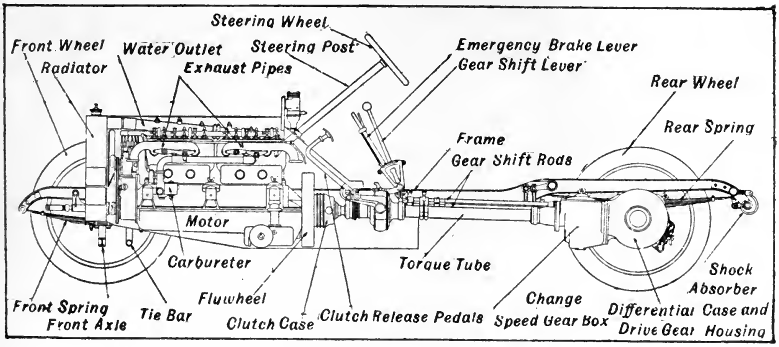


Fig. 3.—Side Elevation of Sheffield-Simplex Six-Cylinder Chassis; a Typical Design of English Derivation.

between the engine shaft and the rear wheel. The steering wheel actuates the mechanism which moves the wheels to the right or left when one wishes to describe the circle, turn a corner, or otherwise deviate from a straight line.

The change speed gear is one of the most important elements of the power transmission system and in connection with the clutch it is much used in operating and controlling the vehicle. The function of the frame has been previously described. The exhaust pipe is employed to convey the inert gases discharged from the motor cylinders to a device known as the muffler which is designed to reduce gas pressure by augmenting the volume and thus diminish the noise made as it issues to the atmosphere. The driving shaft transmits power from the change speed gearset to the bevel gearing in the rear axle.

A universal joint is a positive connection which permits a certain degree of movement between two shafts which must be driven at the same speed. One or the other, or both, may move in a lateral or vertical plane to a limited extent without interrupting the drive or cramping the moving parts. The rear construction houses the differential and driving gears, and the shafts or axles which transmit the power to the traction wheels. Brakes are used to retard, or stop, the movement of the wheels, and are operated by rods which transmit the force the operator applies at the brake pedal or hand lever to the brake band. Torque members are used to maintain a definite relation between the driving gears in the axle and those in gearset, and to take the driving thrusts off the axle and the strains imposed by braking and driving from the springs. The principles underlying operation of each of the parts shown and the number of different forms in which they may exist, will be described more extensively in the chapters dealing fully with the various groups.

Assembling Typical Chassis.—The parts which compose the modern automobile and their relation to each other can be very easily ascertained and understood by even those deficient in mechanical knowledge, by consulting Figs. 8 to 13, inclusive. These show the various steps in assembling a typical American car, and have been prepared by the Locomobile Company to show the ease with which their cars may be assembled, or dismantled.

At Fig. 8, A is shown the bare pressed steel frame which forms the basis of practically all motor cars, before any of the other parts have been added to it. It will be seen that it consists of two side members of pressed steel, these usually being a channel section. The two side members are joined by a series of four cross pieces. The wide one at the front end serves to support the radiator and the starting crank. The two which are placed a little forward of center in the chassis are utilized to support the change speed gear case. The rear cross member is employed solely as a bracing piece, and is reinforced by two triangular gusset plates. All the frame members are securely joined together by steel rivets. It will be noticed that the front end of the frame is narrower than the rear portion. This is to permit the front wheels to assume a more abrupt angle than would be the case if the frame bars were not cambered. This permits one to maneuver the car more easily in narrow streets because it permits one to turn more briskly.

At Fig. 8, B, several parts have been added to the frame. The front springs have been attached directly under the front end, and

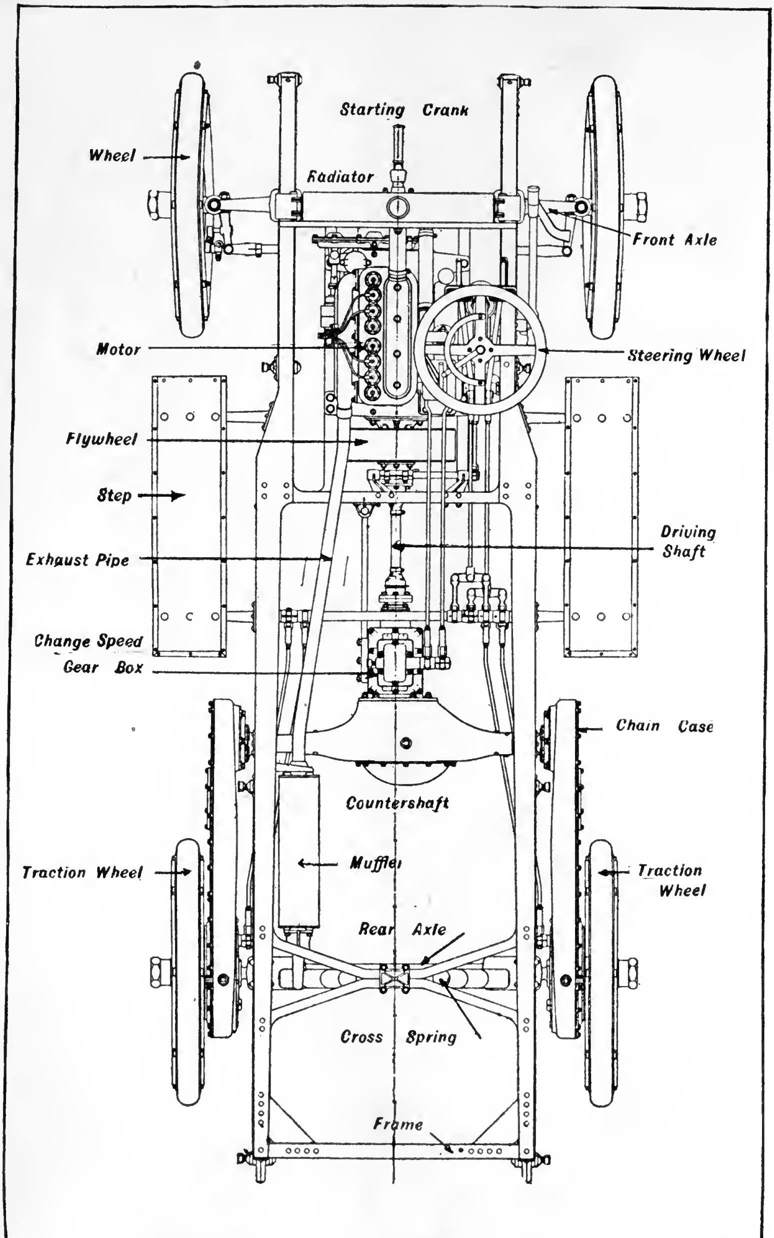


Fig. 5.—Plan View of Light American Motor Truck Chassis.

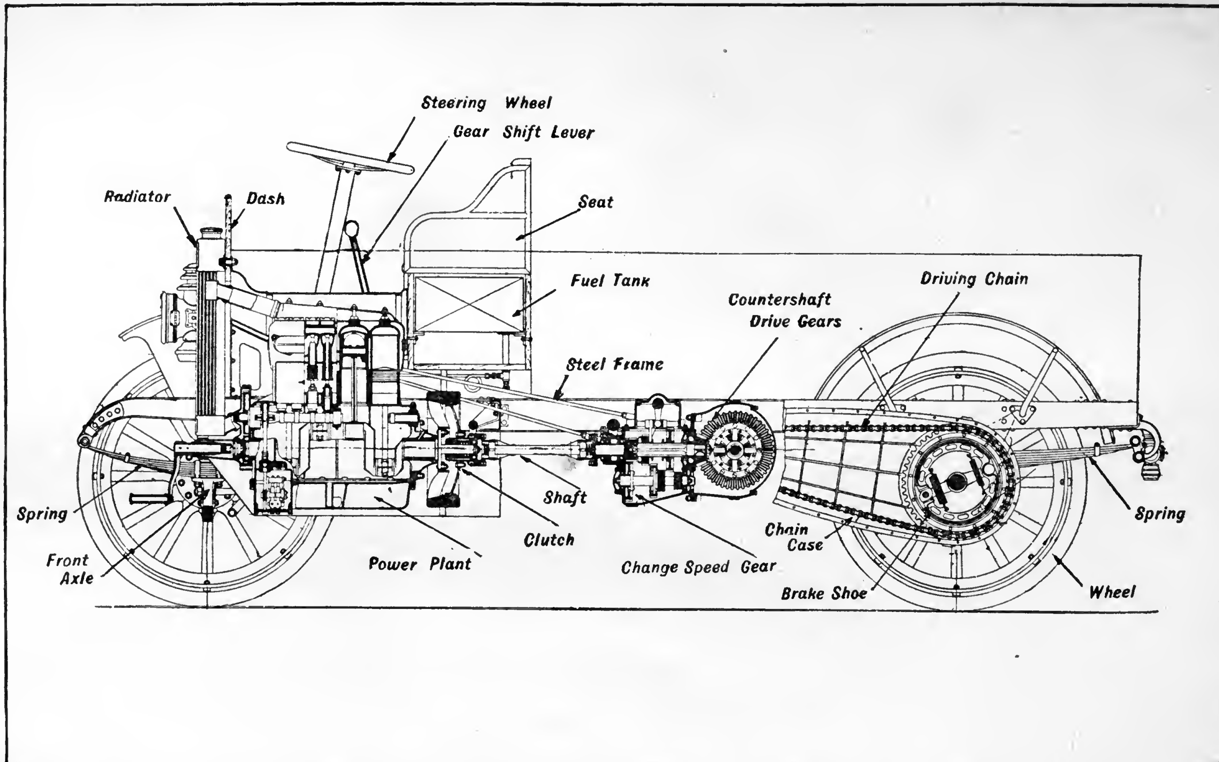


Fig. 6.—Side Elevation of Light Truck Chassis, Showing Important Mechanism.

the front axle has been installed and fastened to the springs by means of clips. The supporting springs at the back end as well as the front and rear shackles or hangers have also been installed. Attention is called to the method of supporting the rear ends of the rear springs

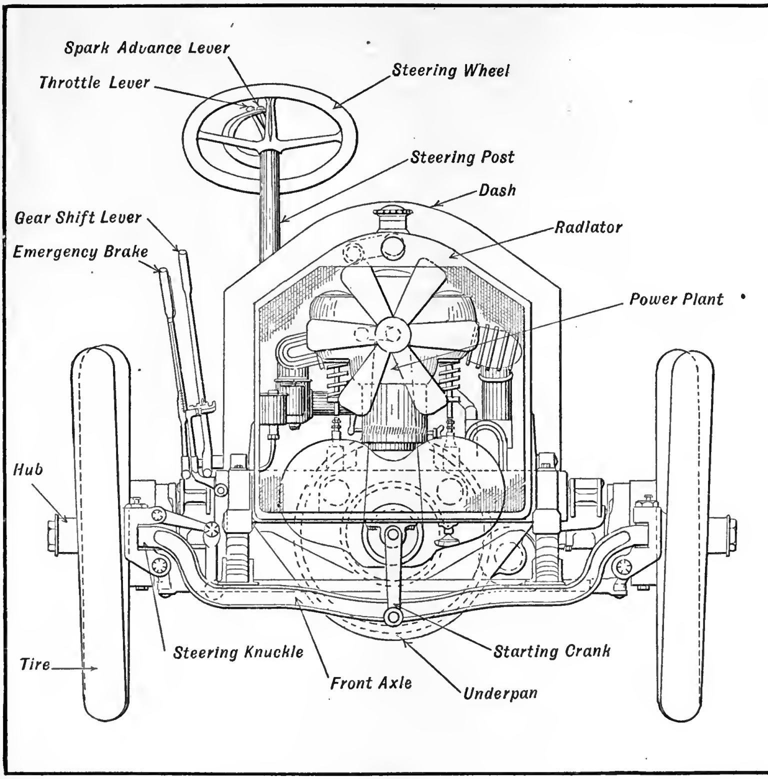


Fig. 7.—Front View of Gasoline Pleasure Car Chassis with Section of Radiator Broken Away to Show Placing of Power Plant in Frame.

by a through bar which passes through the two side members, serving very effectively as an additional brace.

The illustration at Fig. 9, C depicts the chassis after the headlight supporting brackets, or lamp irons, the motor or complete power plant and the dash have been placed in their proper positions. The appear-

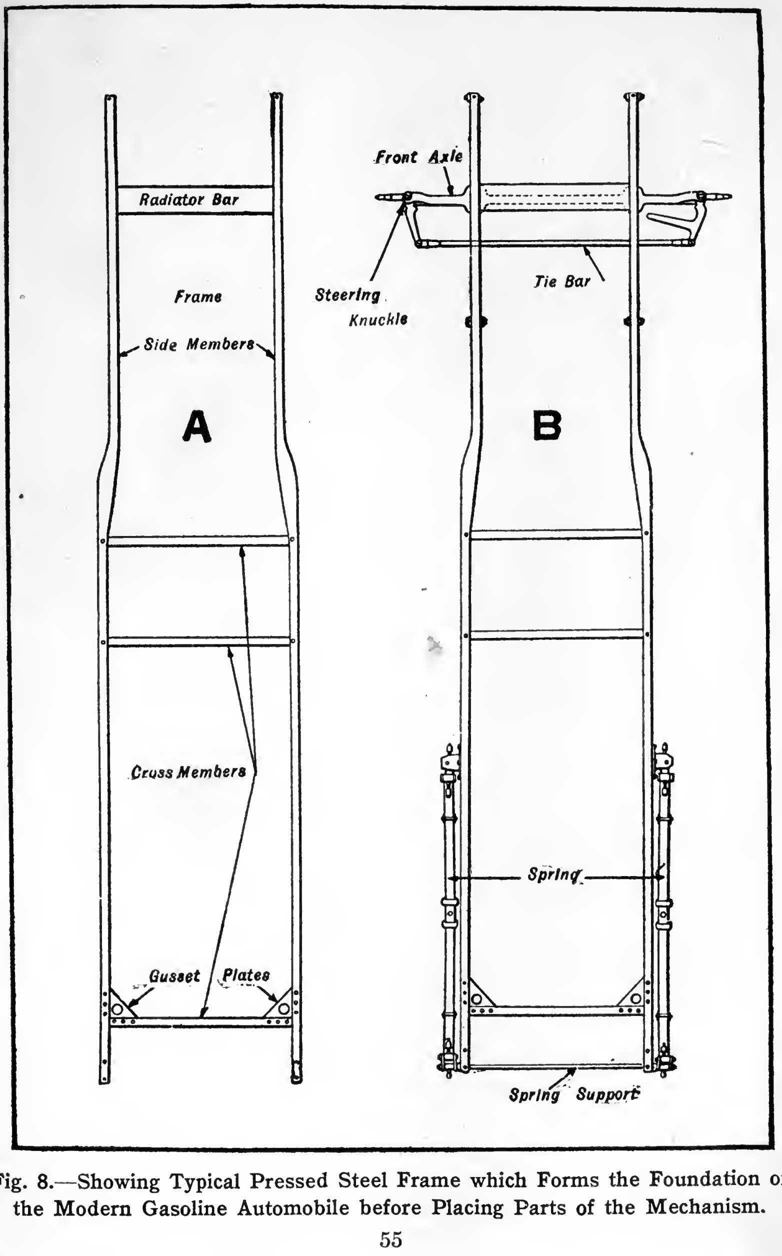


Fig. 8.—Showing Typical Pressed Steel Frame which Forms the Foundation of the Modern Gasoline Automobile before Placing Parts of the Mechanism.

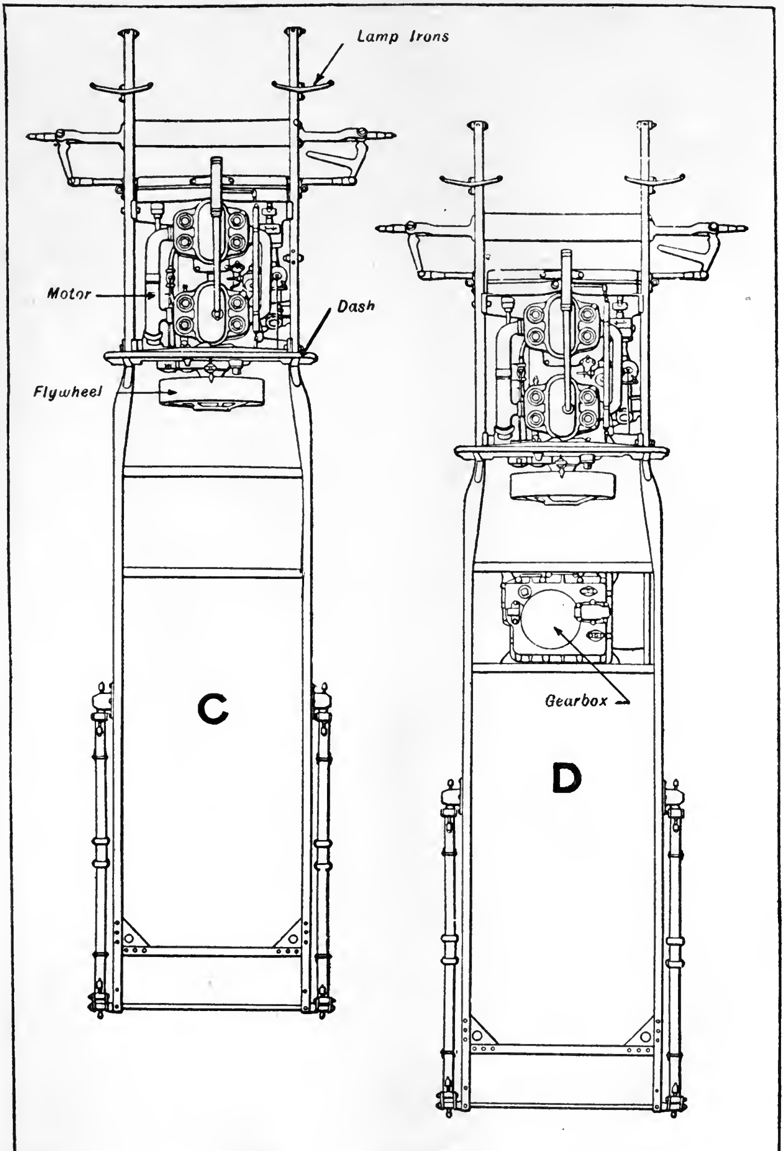


Fig. 9.—Views Detailing Further Steps in Assembling Typical Gasoline Car Chassis, Illustrating Location of Motor and Gear Box.

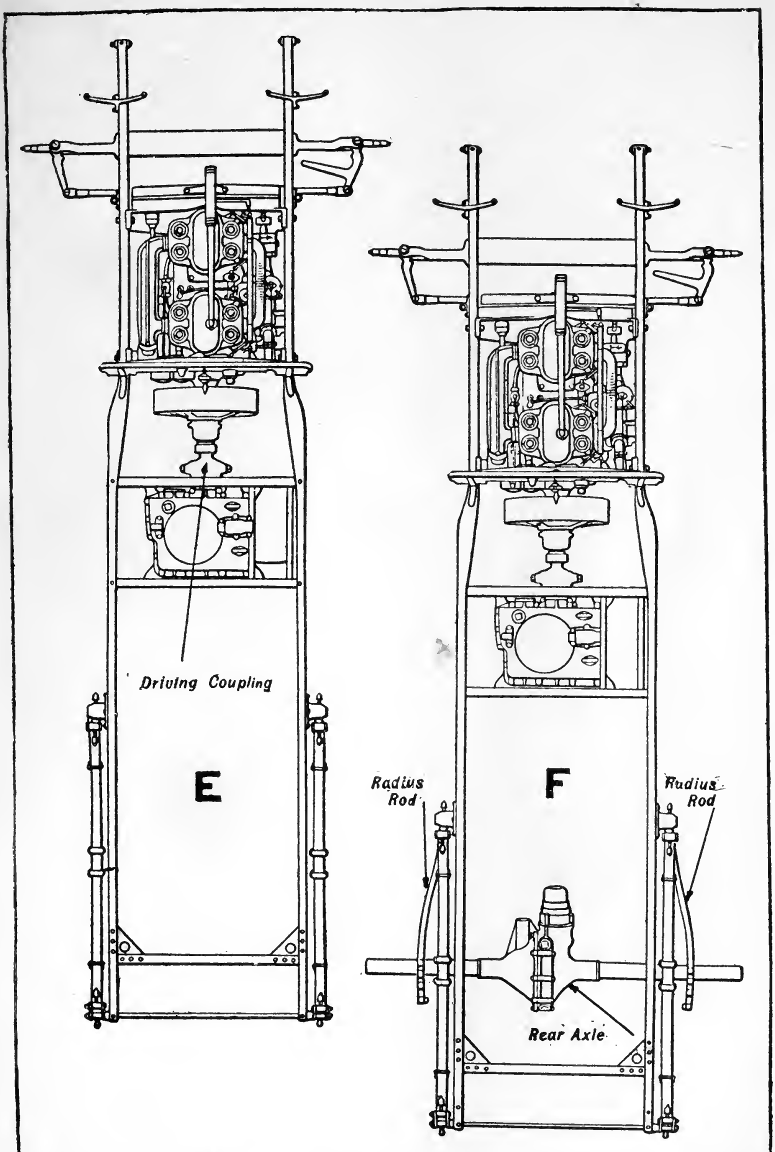


Fig. 10.—How the Pleasure Car Chassis Looks with Rear Axle Installed and Gearset Coupled to Engine.

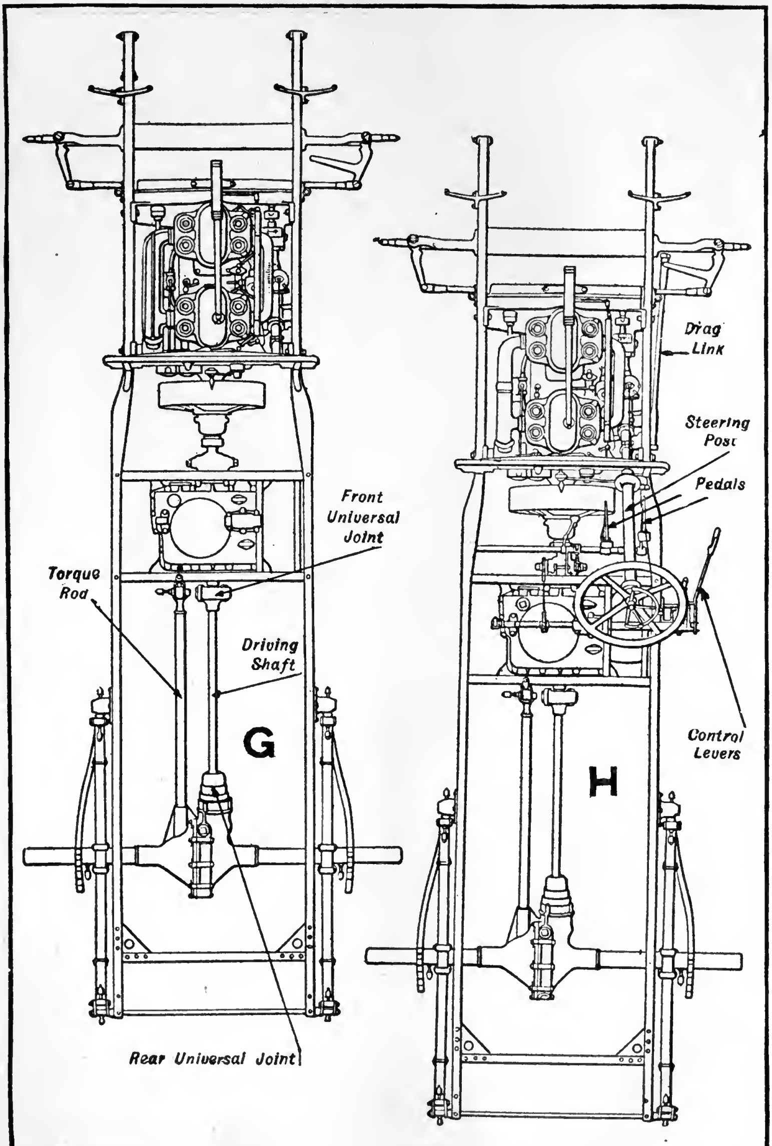


Fig. 11.—After Driving Shaft, Steering Wheel, and Control Levers are Added the Chassis begins to Assume a Finished Appearance.

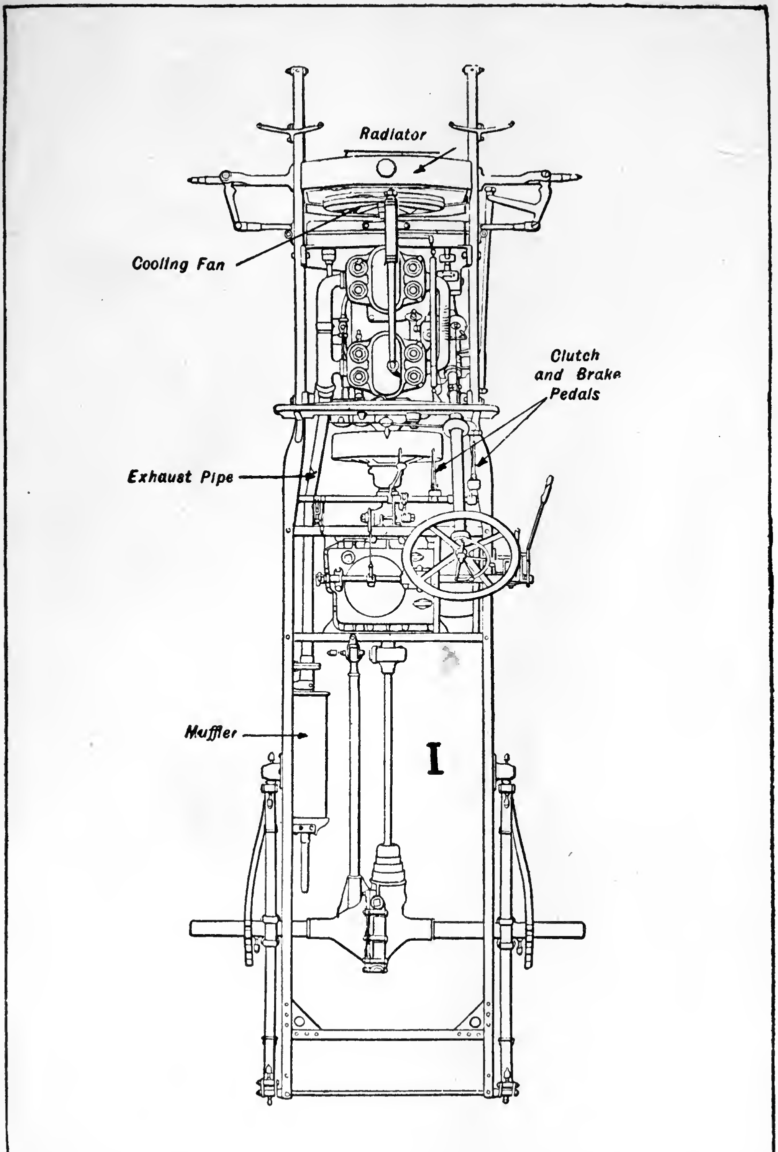


Fig. 12.—Plan View of Chassis when Radiator, Cooling Fan, and Muffler have Been Put in their Proper Places.

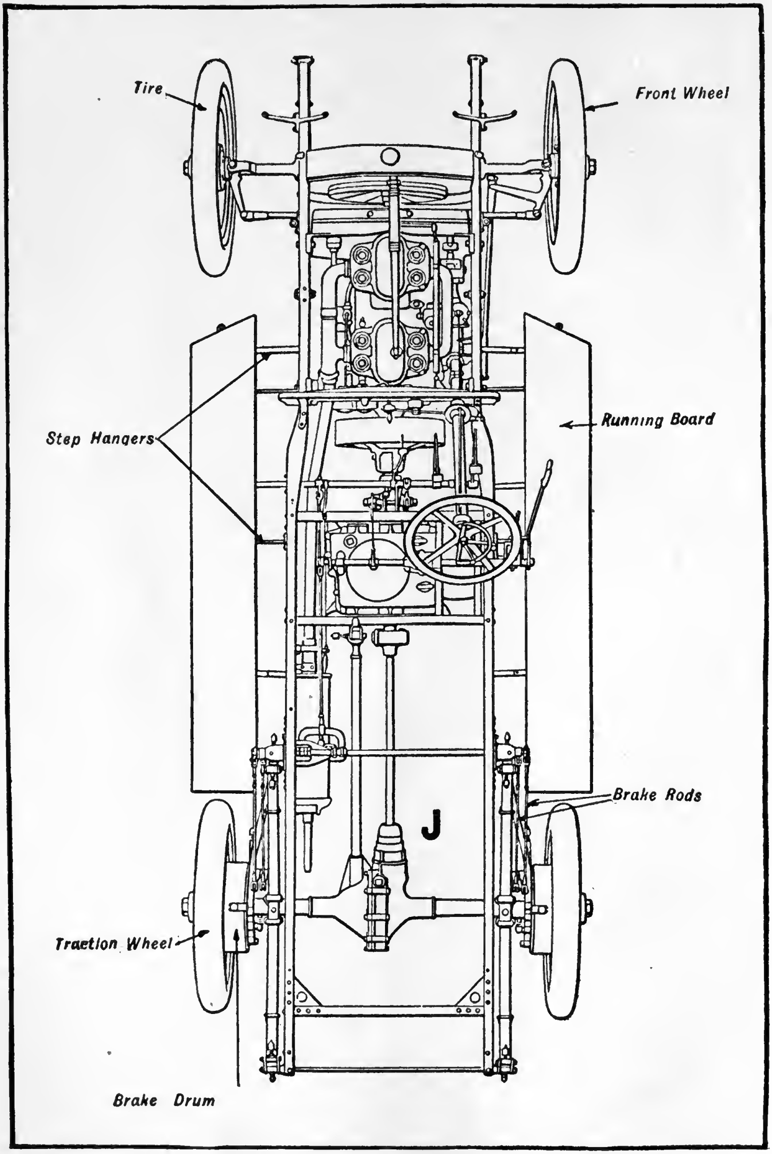


Fig. 13.—The Finished Chassis as it Appears After the Front Wheels, Tires, Traction Wheels, Brake Drums, Running Boards and Finishing Touches Have Been Made.

ance after the change speed gear box has been fastened to the two center cross members is shown at D. It will be noted that the power plant is attached directly to the frame side members by means of arms or lugs extending from the engine base. These are firmly bolted to the frame sides and the motor bed forms a very strong member which serves to keep the two sides of the frame together.

The views at Fig. 10 show further steps in the process of making a motor car. At E, the motor fly wheel has been joined to the gear box by means of a clutch and driving coupling. At F, the rear axle has been bolted to the springs and the radius or distance rods have been installed.

At Fig. 11 the chassis begins to assume a more finished appearance. Referring to G, it will be seen that the gear box has been connected to the rear axle by means of a driving shaft which has a universal joint at each end. The torque rod, which is a member designed to resist braking and driving torque stresses and to maintain a fixed distance between gear box and rear axle, has been put in place. At H, the steering post, on which are placed the motor control levers and steering wheel, has been fastened to the frame side member and the steering mechanism has been joined to the front axle by the drag link. The gear shift and emergency brake levers have also been placed.

Inspection of Fig. 12 will show the radiator and cooling fan on the extreme front of the frame, almost directly over the front axle, and that the power plant has been joined to the radiator by a piece of rubber hose. The exhaust pipe and muffler have also been fitted.

The appearance of the complete chassis, ready to receive the body, is shown at Fig. 13. The parts added are clearly indicated. The front axle has been made complete by the addition of the wheels and tires. The rear construction has also been finished by supplying the traction wheels, tires, and brake drums. The brakes have been connected to the operating pedal and lever by rods; and step hangers, which support the running boards, have been riveted to the frame sides. The chassis, as shown at Fig. 13, is made a finished car by the addition of a suitable body, gasoline tank, sheet metal under-pan to protect the mechanism and mud guards which extend from both extremities of the running board to the front and rear, respectively, over the wheels to protect the body from mud thrown by the wheels.

Wind Resistance and Body Design.—The reader who studies closely modern motor-car design will see that the bodies which are popular at the present time are of different form than those which were formerly used. They are lower and have gradual curved sides. The object of this new construction, or torpedo body, as it is called, is to reduce wind resistance and also lessen the dust-raising proclivities of high speed automobiles. The effect of the air disturbed by a rapidly moving vehicle may be easily observed during the Fall when the weather is settled and the ground is well covered with leaves. When a car is driven along the road at moderate velocities a careful observer will detect movement of leaves fifteen or eighteen feet away from and at the side of the car. This shows that they have been affected by the large volume of air set in motion by the car body. It is obvious that dry dust would be disturbed in a similar manner, and if special attention was not directed toward reducing the air movement any motor car, even if moving at moderate speeds, would leave a cloud of dust in its wake.

Dust disturbance is not the most important factor, however, in determining body form, but it is the resistance of the air that is taken into consideration because of power absorbed. The object in designing should be to reduce end on resistance area to as low a point as possible, because the less area one has to push through the air, the less power it will take to overcome air resistance and more energy can be expended in driving the car.

At Fig. 14, the front view of a typical motor car is shown with dimensions which indicate the approximate size. To ascertain the total area, one or two points require consideration. The radiator, which is the largest member setting at a vertical plane, cannot be considered as offering an area that its overall dimensions would indicate. A large volume of air passes through it, but by no means all the air that passes between the tubes and the radiator discharges without resistance. Some of it flows easily around the power plant, and some streams out under the floor boards, especially if these are inclined. The greater part of the air which passes through the radiator must be deflected by the vertical dashboard which separates the motor compartment from the body, and the reaction due to this cause is comparable to the resistance which would obtain if the radiator was practically solid. It is estimated that the resistance of the average radiator may be safely considered at about half that of a solid plane surface of equal dimensions.

The resistance of the curved mud guards can be assumed to be that of their projected area, because the usual angle of inclination is

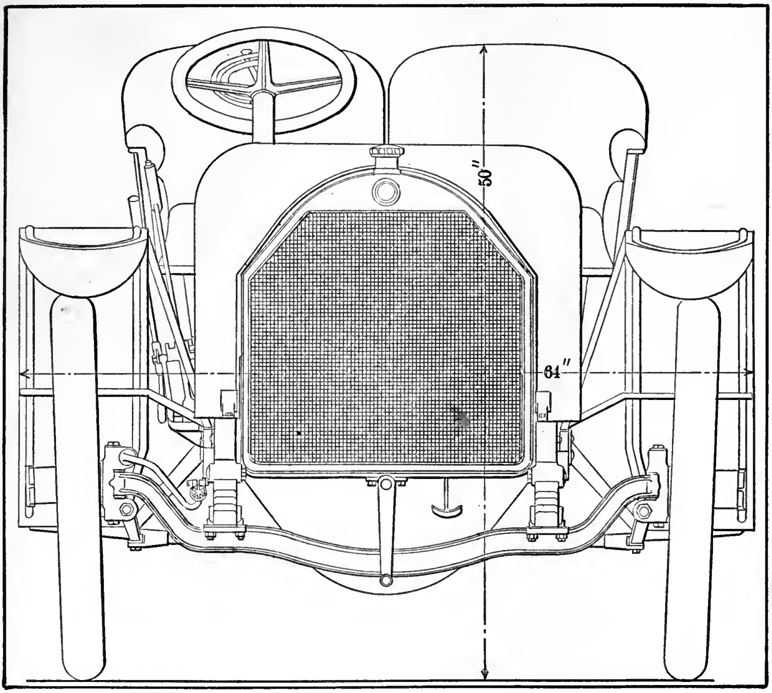


Fig. 14.—Front View of Typical Gasoline Car of Modern Design, Showing Parts which Tend to Impede Speed of Car by Producing Air Resistance.

such that the total pressure upon their underside may be taken as the same that would exist if they were not inclined appreciably. In addition, one may figure the area of a wind shield and top, and when all these factors are considered, the approximate end on resistance of the average touring car will vary from twenty to twenty-five feet.

The amount of power which will be needed to overcome this resistance can be easily computed on a basis of speed of thirty miles per hour. The power required to overcome air resistance varies as the cube of the speed, and therefore if the velocity is doubled, making it sixty miles per hour, the power absorbed at half that speed will be increased in value eight times. The following table indicates the power absorbed by air resistance at various speeds, assuming a total end on area of twenty-three square feet:

M. P. H.	H. P. Absorbed	M. P. H.	H. P. Absorbed
10	.174	50	21.75
20	1.392	60	40.00
30	4.698 ~~5.000~~	70	59.68
40	11.136	80	89.08

If one consults the table presented above it will be evident that cars running at speeds of thirty miles per hour, or less, are not seriously affected by air resistance, but just as soon as the speed augments it will be apparent that it is very desirable to reduce the frontal area directly exposed as low as possible

At Figs. 15 and 16, diagrams are presented to indicate the probable direction of the air currents around an ordinary type fore door

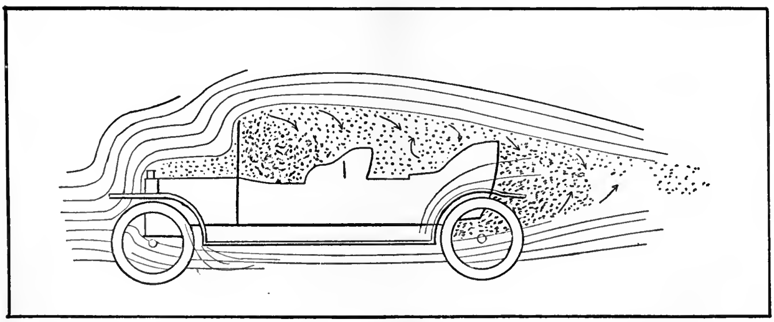


Fig. 15.—Side View of Typical Gasoline Car, Demonstrating Influence of Body Form on Air Flow.

body with square dashboard and wind shield raised to a vertical position. These may be compared to advantage with the views shown at Figs. 17 and 18, which represent the same phenomena, except that the car is provided with a better designed body and a tapered hood, and that the wind shield is tilted instead of being set vertical. The diagrams are very instructive, and it should be noted in this connection that eddy currents would be largely increased if no side doors were fitted to the front seats. With a body of the stream line form the air currents are not deflected abruptly but follow the outline of the curved body and do not tend to raise as much dust or offer the same resistance as that present at Figs. 17 and 18.

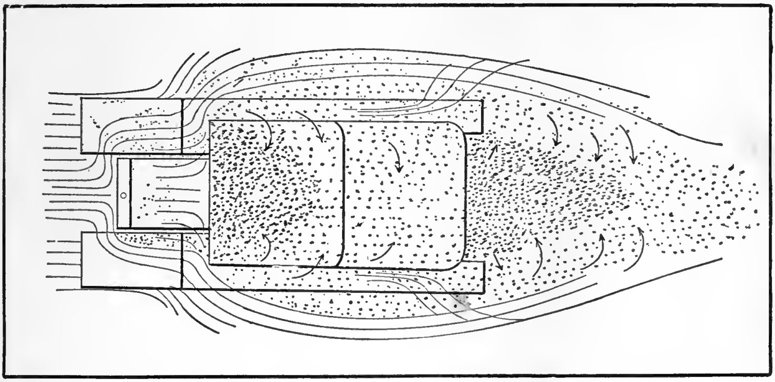


Fig. 16.—Plan View Showing Path of Air Currents Around Body of Gasoline Car when No Attempt Has Been Made to Secure Lessened Air Resistance.

In order to show how much resistance may be obviated by the use of a stream line body, it is well to consider a typical example. Consider a car which is equipped with a seventy-horse-power engine and which track tests have demonstrated capable of ninety miles per hour. From the horse power available for overcoming the wind resistance we can deduct a certain amount which will be absorbed by friction of the transmission mechanism and loss between tires and track. The loss due to the driving gearing can be assumed to be twenty-five per cent, and that due to loss between tires and roadway is estimated at ten per cent. This will make a total loss of thirty-five per cent, which result will be sufficiently near the truth for purpose of approximation. The available horse power is therefore sixty-five per cent of seventy horse power, or in round numbers forty-five horse power. It would seem that the less area one had the greater speeds possible with the horse power available. In order to attain a speed of ninety miles per hour one could only have an exposed area of about eight square feet.

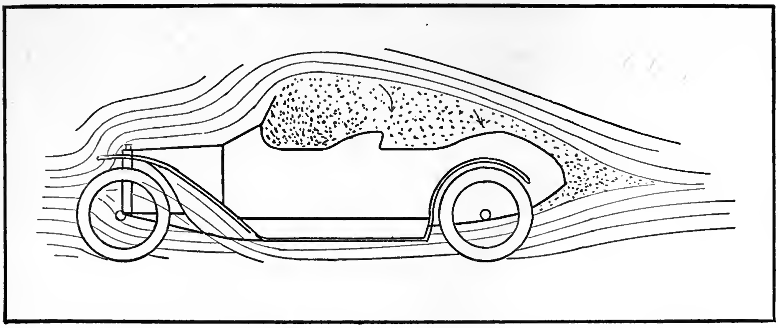


Fig. 17.—Depicting Flow of Air Currents Around Torpedo Body; Designed to Reduce Friction of Atmosphere at High Speeds.

This would call for a stream line form racing body similar in design to that shown at Fig. 19. It will be seen that the air currents

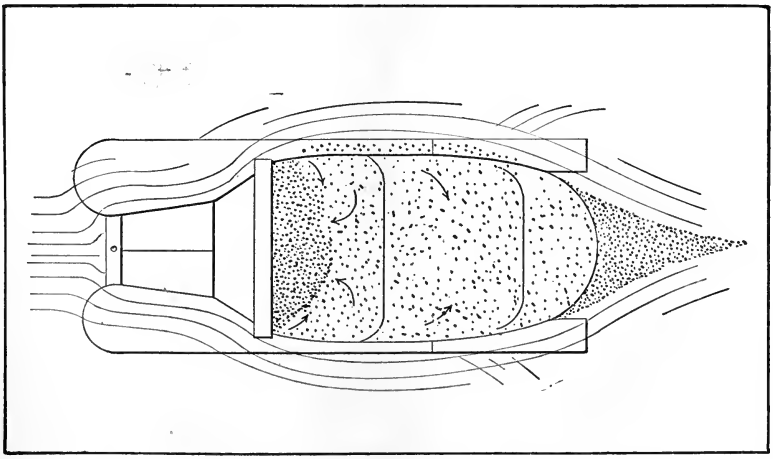


Fig. 18.—Plan View of Vehicle Body Shown in Preceding Illustration, which Clearly Indicates Influence of Symmetrical Body Form in Promoting Lessened Air Resistance.

follow the body contour very closely. As the body is flush sided with no openings or projections to disturb air flow, it will be evident that the minimum of exposed area will permit a maximum speed. Obviously, a practical touring car cannot be designed on exactly the same lines as a racing vehicle, as too much of the operator's comfort would have to be sacrificed to attain this end. A practical form of stream line body fitted to a roadster chassis is shown at Fig. 20, while a fore-door, five-passenger touring car is depicted in outline at Fig. 21.

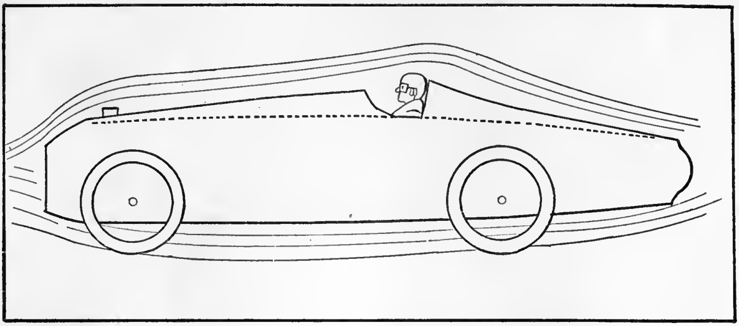


Fig. 19.—Outline of Exaggerated Torpedo Body Type, Seldom Seen Except in Racing Cars.

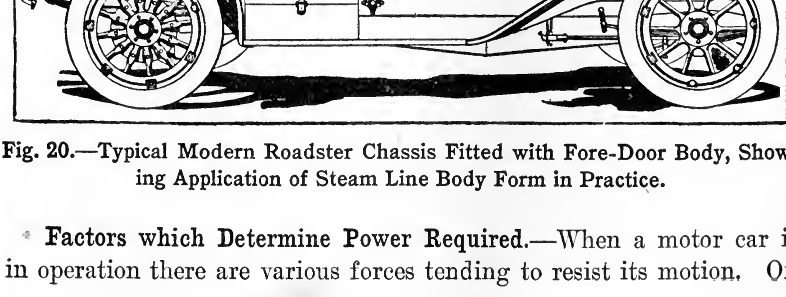


Fig. 20.—Typical Modern Roadster Chassis Fitted with Fore-Door Body, Showing Application of Steam Line Body Form in Practice.

Factors which Determine Power Required.—When a motor car is in operation there are various forces tending to resist its motion. On a level road these are the rolling resistance at the point of contact of the traction wheels and the roadway; friction in the power transmission mechanism and atmospheric resistance. If the vehicle is

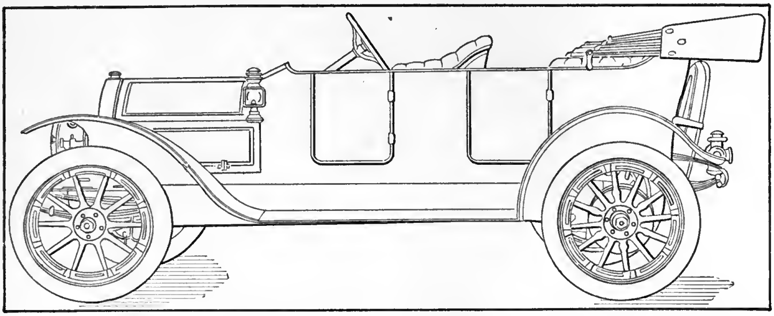


Fig. 21.—Application of Fore-Door, Five-Passenger Touring Body to Gasoline Car Chassis.

moving on a gradient there is still another factor to be considered, and this is the amount of power needed to raise the weight of the car against the force of gravity. Obviously when the car is descending a hill the force of gravity assists the power plant instead of working against it.

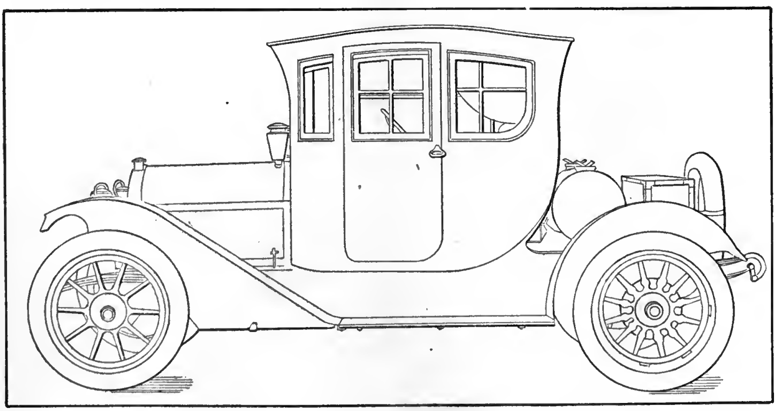


Fig. 22.—The Coupé, a Popular Form of Closed Body Favored by Professional Men.

The resistance of the road depends very largely upon the nature of the surface, and it is also dependent upon the size of the wheels and type of tire with which they are fitted. The second item, that of friction of rear axle, drive shaft, bearings and change speed gears, is comparatively low, and it is generally included with that of road resistance. It will be evident that other factors must also be considered in determining power required to propel a vehicle. One must figure on the total weight of the car, the capacity of the body, and

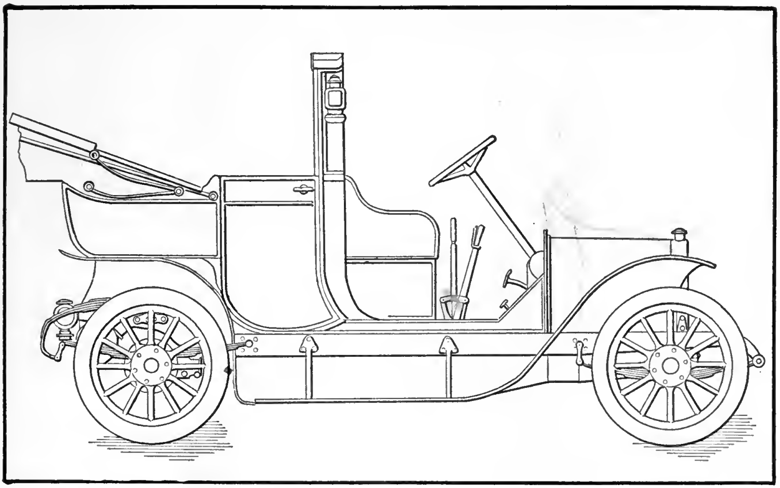


Fig. 23.—The Rockwell Taxicab, or Public Service Vehicle, with Convertible Type Body, which May be Used as Shown and which Becomes a Closed Car when the Top is Raised.

the maximum speed it is desired to attain. All of these factors are considered by the designer, but the usual practice is to assume an average set of conditions and to provide a motor of more power than is absolutely needed to secure a margin of safety over the requirements.

Classification of Motor-Car Types.—In considering the automobile one may divide it into a number of distinct types. These in turn belong to one of two main classifications. When cars are used for industrial purposes, such as hauling freight and delivering merchandise, they are commonly termed commercial cars, or motor trucks. If the automobile is used solely for transporting people such as in touring, or even for business purposes, it is termed a pleasure car, though the line of demarcation between one class and the other is sometimes difficult to define.

There is no great difference in construction of the essential elements of either form. One chassis may be fitted with many different body types, some of which may be specially designed for commercial use while others may be intended solely for personal transportation. The

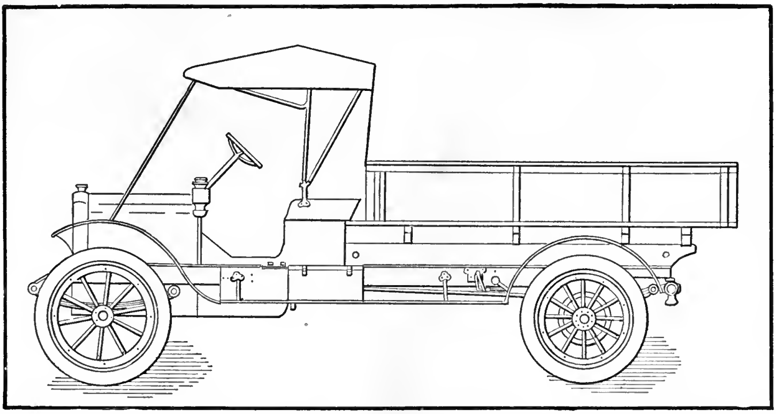


Fig. 24.—One-and-one-half Ton Capacity White Truck; a Conventional Example of American Commercial Car Having Power Plant Located Under the Hood, as in Pleasure Car Practice.

chassis of the vehicle contrived solely for use in conveying merchandise is built heavier and stronger than one built only to carry passengers, and there are certain modifications in detail. The principles of operation of the essential elements such as power plant, control systems, driving means, axle construction, etc., are the same, and no attempt will be made to differentiate between the types except in cases where the construction differs radically from accepted or general practice.

As an example of the difficulty in isolating the types a form which may belong to either classification is shown at Fig. 23. If used as a town car for social calls, shopping, etc., it might be classed properly as a pleasure car, whereas if employed as a public-service vehicle, or taxicab for hire, it belongs to the other classification. The

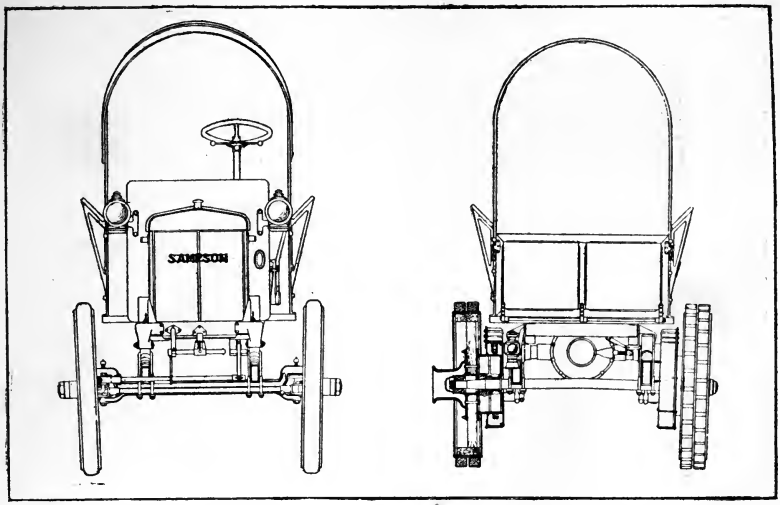


Fig. 25.—Front and Rear Elevation of Special Sampson Truck, Designed for United States Army Service.

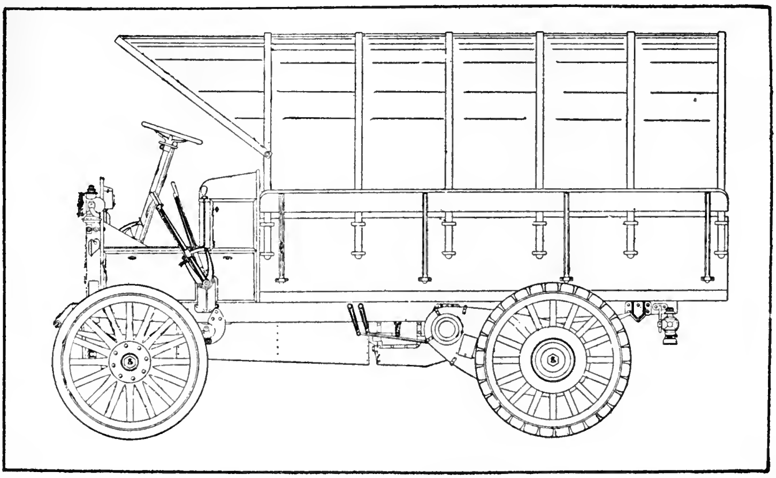


Fig. 26.—Side View of Sampson Army Type Transport Wagon.

truck shown at Fig. 24 is a good example of the way pleasure car practice may be altered for commercial purposes. The parts are strength-

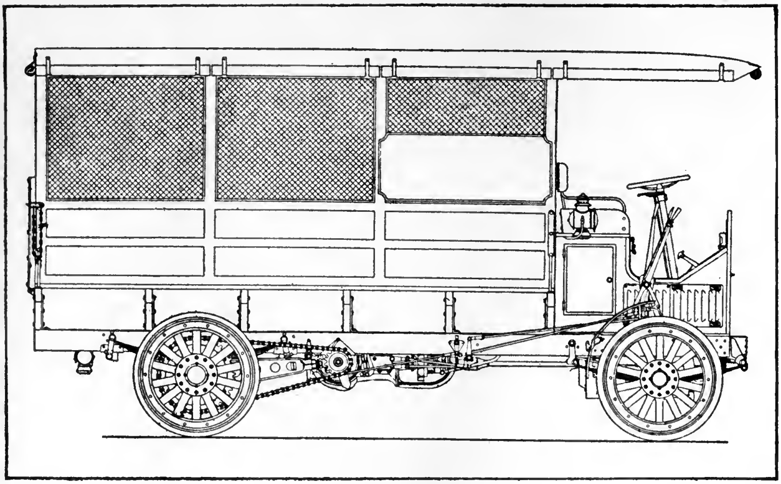


Fig. 27.—Showing Typical American Motor Truck Design in which Power Plant is Placed Under Operator's Feet, thus Providing More Carrying Space for Body without Lengthening Wheel Base.

ened, but the general design as regards disposition of the parts of the mechanism is very similar to that which obtains in representative

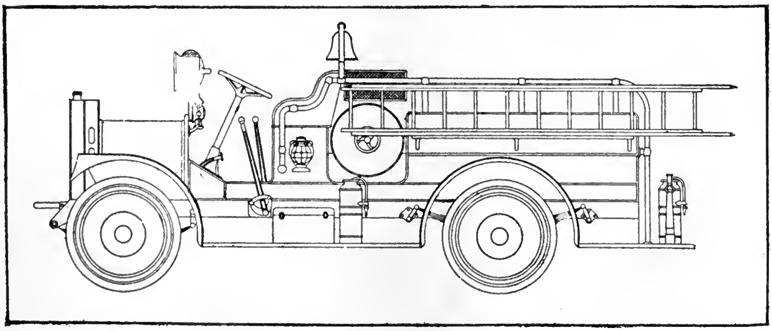


Fig. 28.—Motor Truck Chassis Fitted with Special Body for Fire Department Service; a New Field to which the Gasoline Motor is Particularly Well Adapted.

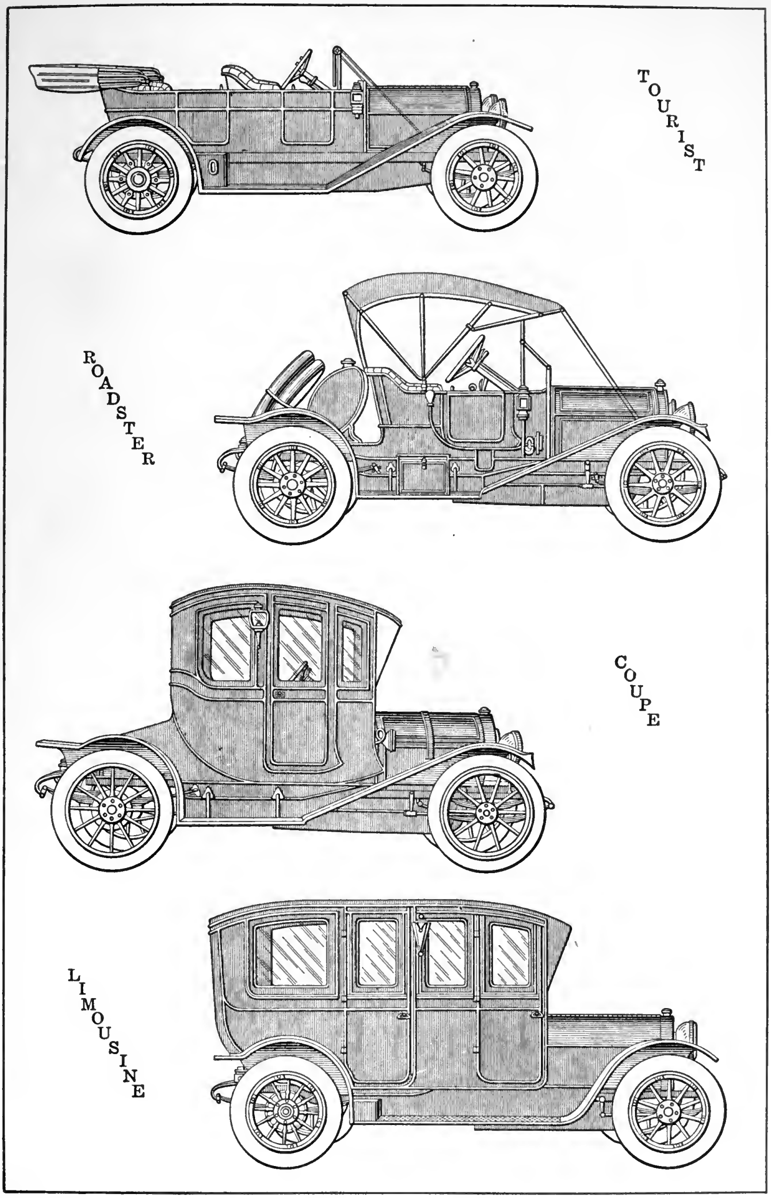


Fig. 29.—Showing Different Body Forms Fitted to Same Chassis Type.

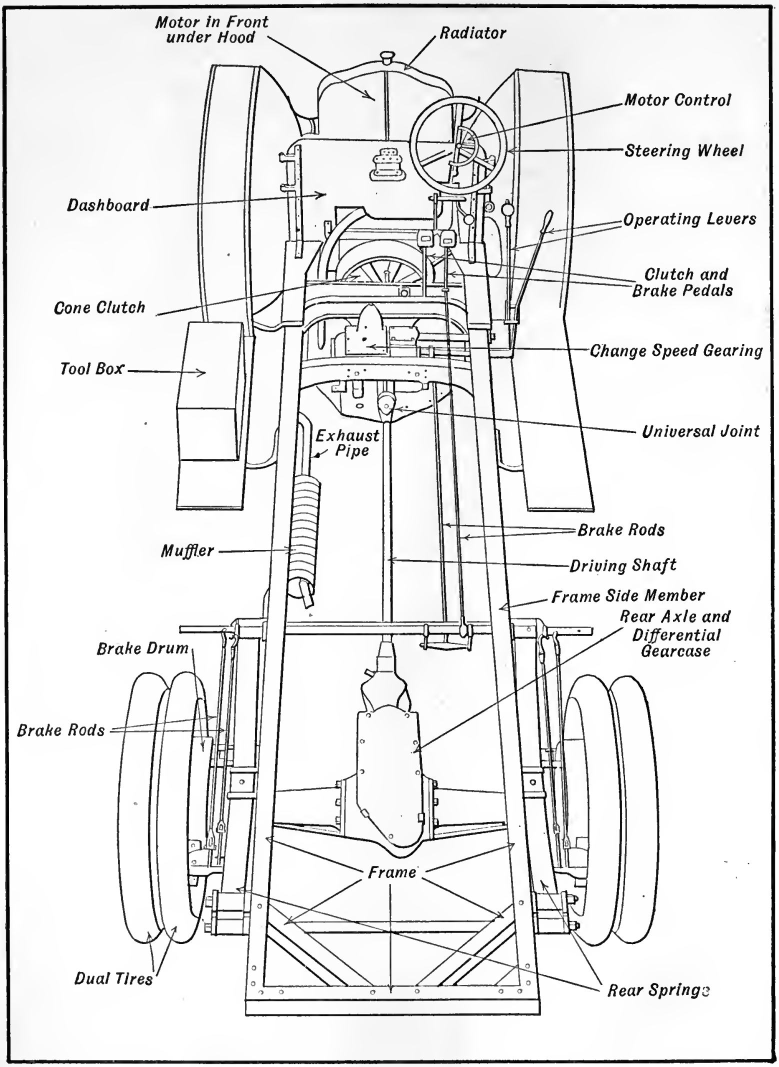


Fig. 30.—Light Motor Truck Chassis which Follows Typical Pleasure Vehicle Design Except in Size of Parts. The Frame and Running Gear are Heavier and Stronger to Compensate for the Greater Load-Carrying Capacity.

pleasure cars. Figs. 25 to 28 inclusive, depict vehicles which have been designed for special industrial requirements and can be placed in the commercial car class without hesitation, because the bodies fitted and the general design or arrangement of components does not permit their use for any purpose other than that for which they were contrived. All the body forms shown at Fig. 29 are applied to the same type chassis, and it is very common practice to design the running gear and frame so it may be adapted to a wide range of work without changing location of the mechanical parts.

CHAPTER II

How Power is Generated—Two- and Four-Cycle Engine Action—Features of Sleeve Valve Motor—Principal Engine Types Described—One- and Two-Cylinder Engines—Advantages of Four- and Six-Cylinder Forms—Power Plant Location.

It has been previously stated that the gasoline automobile may be divided into groups and that these various assemblies all have their important work to do and that each depend, to some extent, upon the correct action of the others to insure a smooth working motor car. The most important, and the least understood, element is the power plant, and it is important that the prospective motorist familiarizes himself with the principles of gasoline engine operation in order to easily locate troubles and derangements which interfere with correct action. If the operator is familiar with the basic principles of internal combustion engine action it will not be difficult to apply this knowledge to all forms of gasoline motors used as automobile power plants.

Forms of Engines Commonly Used.—If one raises the hood at the front of a motor car, one will find a complete engine assembly very much the same as that depicted at Fig. 31, which outlines a conventional engine with the various auxiliary parts lettered so that one can obtain an idea of their location relative to each other.

Of the external parts shown the carburetor is employed to mix the gasoline used as fuel with a certain amount of air in order to form a gas that can be ignited in the engine cylinders. This explosive mixture is supplied to the cylinders by a conductor known as the inlet pipe. The spark plugs and magneto form part of the ignition outfit. The engine shown is a four-cylinder form and operates on the four-cycle principle. Various forms of engines have been applied to automobile propulsion, and of the large number of different types the majority operate on the four-stroke principle, though the two-stroke types are simpler. In the latter there is an explosion in each cylinder every turn of the crank shaft, while the other method provides but one power impulse per cylinder every two turns of the revolving elements. Though the four-stroke motor is more complicated in construction than the other it is the easiest to understand. All internal combustion motors, usually termed "gasoline engines" because of the use of this liquid fuel, are forms of heat motors owing to the

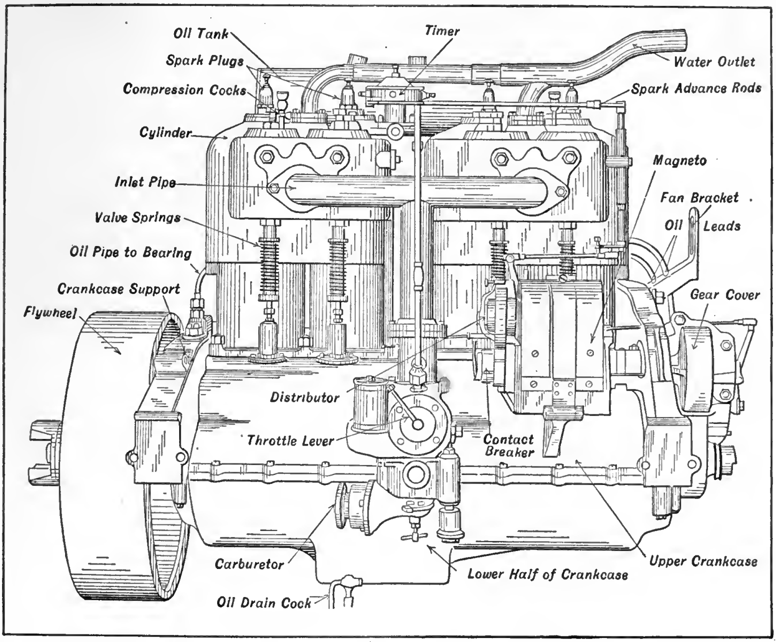


Fig. 31.—Typical Motor-Car Power Plant, Showing External Appearance and Location of Important Auxiliary Mechanisms.

energy being produced by the rapid burning, or combustion, of a gas which expands after it is exploded and produces pressure that is transformed into mechanical power by simple mechanism. In defining the principles of four-cycle motor action, one can explain the matter very clearly by comparing the effect produced by exploding gasoline gas to that which obtains when one explodes gunpowder in a gun.

How the Gasoline Engine Works.—At Fig. 32, A, the upper view shows a section through a simple one-cylinder gasoline engine, while the lower one illustrates an old pattern muzzle loading cannon. Considering first the phenomena which obtains when gunpowder is burned, one can obtain some idea of how exploded gasoline vapor may be transformed into power. In fact, the preliminary operations which have been necessary before the gun was fired, are very similar to those which preceded an explosion in the cylinder of the gasoline engine of the four-cycle type. Following first the cycle of operations necessary to fire the cannon, graphically shown at the lower portion of Fig. 32, it will be seen that a certain sequence is necessary. At A we have the loading, or charging of the mortar. The powder which is carried in bags for convenience is introduced in the muzzle and pushed back into the breech with the ramrod. After the powder has been compressed the ball is placed and tightly rammed in place on top of the powder in the explosion chamber, as shown at B. After the powder is properly compacted it is exploded by means of a lighted fuse, or percussion cap, and the cannon ball is forced out through the open end because of the pressure of gas on its underside, this having been produced by the rapid burning of the powder.

The next operation is clearing the mortar of the burned gases in order to introduce a fresh charge of powder and shot. The clearing is automatically performed, as shown at D. As soon as the ball leaves the mouth of the mortar the gas which is still under high pressure escapes to the atmosphere. After the barrel is swabbed out, one can introduce another charge and fire the cannon again. The power to propel the shot through the air has been obtained by burning a substance which before ignition had no power to produce motion of the ball. If an equal charge of gunpowder had been placed in the open air and the shot placed upon it, one would find that if the combustible material were ignited, there would be very little energy produced. There would be a flash of flame, but it is doubtful that this would have sufficient energy to cause the cannon ball to leave its position. Powder compacted in the cannon barrel produced useful energy because pressure was confined in a chamber having rigid walls at all sides, except one, this being the side of the cannon ball nearest the explosive. The metal surrounding the explosion chamber had sufficient strength to resist the high gas pressure, but the ball which was movable was driven out because its weight was not sufficient to resist the force applied to it by the exploded powder.

It is evident that burning powder in the air will produce a certain amount of energy, but as the explosion takes place in the open there will be nothing to restrain the pressure, and just as soon as the powder is lighted any energy evolved is dissipated into the atmosphere instead of the force being directed against yielding members. The ball is forced out of the gun barrel, not only by the gas pressure which results as soon as the powder is exploded, but also by the expansion of the gases generated by combustion which tends to accelerate its motion toward the end of the barrel. As the shot moves toward the end and the gas occupies more space its pressure becomes less, and when the ball leaves the mouth of the motor there is very little power remaining in the moving gas. There is sufficient pressure, however, so that the gas rushes out of the interior and the barrel is thus cleared of inert products which have no useful force.

The action of a modern repeating rifle is somewhat different than that of a muzzle loader, because the powder is already compressed in metal shells which are introduced at the breech of the gun instead of at the muzzle. The number of shells are carried in a magazine, and after one of these explodes the recoil due to the explosion of the gas supplies another charged shell to the breech and the operation of firing the gun may be repeated as long as the supply of ammunition in the magazine lasts.

The modern gasoline engine follows the action of both the old type muzzle loader and the more modern form in which the shell is introduced at the breech. Referring again to sketches at top of Fig. 32, we can compare the action of a simple four-stroke engine with that of a cannon which is illustrated below them. The principal elements of a gas engine are not difficult to understand and their functions are easily defined. In place of the barrel of the gun one has a smoothly machined cylinder in which a small cylindrical or barrel-shaped element fitting the bore closely may be likened to a bullet or cannon ball. It differs in this important respect, however, as while the shot is discharged from the mouth of the cannon the piston member sliding inside of the main cylinder cannot leave it, as its movements back and forth from the open to the closed end and back again are limited by simple mechanical connection or linkage which comprises crank and connection rod. It is by this means that the reciprocating movement of the piston is transformed into a rotary motion of the crank shaft.

The fly wheel is a heavy member attached to the crank shaft which has energy stored in its rim as the member revolves, and the momentum of this revolving mass tends to equalize the intermittent pushes on the piston head produced by the explosion of the gas in the cylinder. If some explosive is placed in the chamber formed by the piston and closed end of the cylinder and exploded, the piston would be the only part that would yield to the pressure which would produce a downward movement. As this is forced down the crank shaft is turned by the connecting rod, and as this part is hinged at both ends it is free to oscillate as the crank turns, and thus the piston may slide back and forth while the crank shaft is rotating or describing a curvilinear path.

In addition to the simple elements described it is evident that a gasoline engine must have other parts. The most important of these are the valves, of which there are two to each cylinder. One closes the passage connecting to the gas supply and opens during one stroke of the piston in order to let the explosive gas into the combustion chamber. The other member, or exhaust valve, serves as a cover for the opening through which the burned gases can leave the cylinder after their work is done. The spark plug is a simple device which may be compared to the fuse or percussion cap of the cannon. It permits one to produce an electric spark in the cylinder when the piston is at the best point to utilize the pressure which obtains when the compressed gas is fired. The valves are open one at a time, the inlet valve being lifted from its seat while the cylinder is filling and the exhaust valve is opened when the cylinder is being cleared. They are normally kept seated by means of compression springs. In the simple motor shown at Fig. 32, the exhaust valve is operated by means of a pivoted bell crank rocked by a cam which turns at half the speed of the crank shaft. The inlet valve operates automatically, as will be explained in proper sequence.

Considering the view shown at Fig. 32, A, the first necessary operation is charging the cylinder with explosive material. The piston is at the top of its stroke and it moves toward the open end of the cylinder. The engine works as a pump, and the piston draws in a charge of combustible gas through the open intake valve, which is in connection with the vaporizer which furnishes the gas. An automatic valve opens because of a light vacuum or suction existing when the piston has traveled down a certain portion of its stroke, and then the outside air pressure is greater than that in the cylinder. The external air pressure is greater than the tension of the spring which tends to keep the valve closed and the member is therefore drawn from its seat by the piston. At the end of the intake stroke, which is shown at Fig. 32, A, and after the cylinder has filled with gas the pressure inside and outside is the same and the valve spring closes the intake valve. As the exhaust valve spring is very strong this member has not been lifted from its seat by the difference in pressure. The exhaust valve is opened by mechanical means solely and only when operated by the cam and push-rod mechanism.

The condition in the cylinder and the gas engine after the piston has reached the bottom of its stroke is very much the same as that which obtains in a gun of the muzzle-loading type after the explosive charge has been introduced. We have learned that, to obtain power from gunpowder, it was necessary to compact it firmly in the combustion chamber of the gun. The gasoline gas which has been taken into the engine cylinder must also be compressed before it is ignited, in order to obtain power. It is compacted into one-third or one-quarter of its former volume, and whereas its pressure is about fifteen pounds per square inch before it is compacted at the end of the compression stroke of the piston the pressure will be increased to forty-five, sixty, and even seventy-five pounds per square inch. At the end of this compression stroke, which is shown at B, the conditions in the engine cylinder are the same as those which prevail in the barrel of the cannon after the powder has been tightly rammed in the closed end of the gun barrel and the ball is forced in on top of it. At C we have seen that the powder was fired by means of a fuse. The compressed gas in the engine cylinder is exploded electrically by a spark occurring between the points of the spark plug. The explosion in the cannon drives out the ball, while that in the engine cylinder forces the piston out and causes the crank shaft and fly wheel attached to it, to revolve.

In order to obtain a perfectly tight combustion chamber, both intake and exhaust valves are closed before the gas is ignited, because all of the pressure produced by the exploding gas is to be directed against the top of the movable piston. When the piston reaches the bottom of its power stroke, as indicated at D, the exhaust valve is lifted by means of the bell crank which is rocked because of the point or lift on the cam. The cam shaft is driven by positive gearing and revolves at half the engine speed. The exhaust valve remains open during the whole of the return stroke of the piston, and as this member moves toward the closed end of the cylinder it forces out burned gases ahead of it, through the passage controlled by the exhaust valve. The cam shaft is revolved at half the engine speed because the exhaust valve is raised from its seat during only one stroke out of four, or only once every two revolutions. Obviously, if the cam was turned at the same speed as the crank shaft it would remain open once every revolution, whereas the burned gases are expelled only once in two turns of the crank shaft.

It will be evident that three strokes of the piston are necessary to secure one useful explosion just as practically three operations are needed to fire the cannon. The first downward movement of the piston fills the cylinder with gas and is known as the "intake stroke." This is accomplished during the first half revolution of the crank shaft. The return movement of the piston is accomplished during the second half of the first revolution and compacts the gas previously inspired. This is called the "compression stroke." The expansive force back of the piston produced by the explosion forces the piston down again, this turning the crank shaft through the first half of the second revolution which is known as the "power stroke." The last half of the second revolution produces a return movement of the piston toward the closed end, and as the burned gases are expelled and the cylinder is cleared to receive the fresh charge, this movement of the piston is known as the "exhaust stroke." The cycle of operations described is continued and repeats as long as the cylinder is supplied with fuel, the spark takes place to fire the gas and the engine prevented from overheating by means of lubrication between

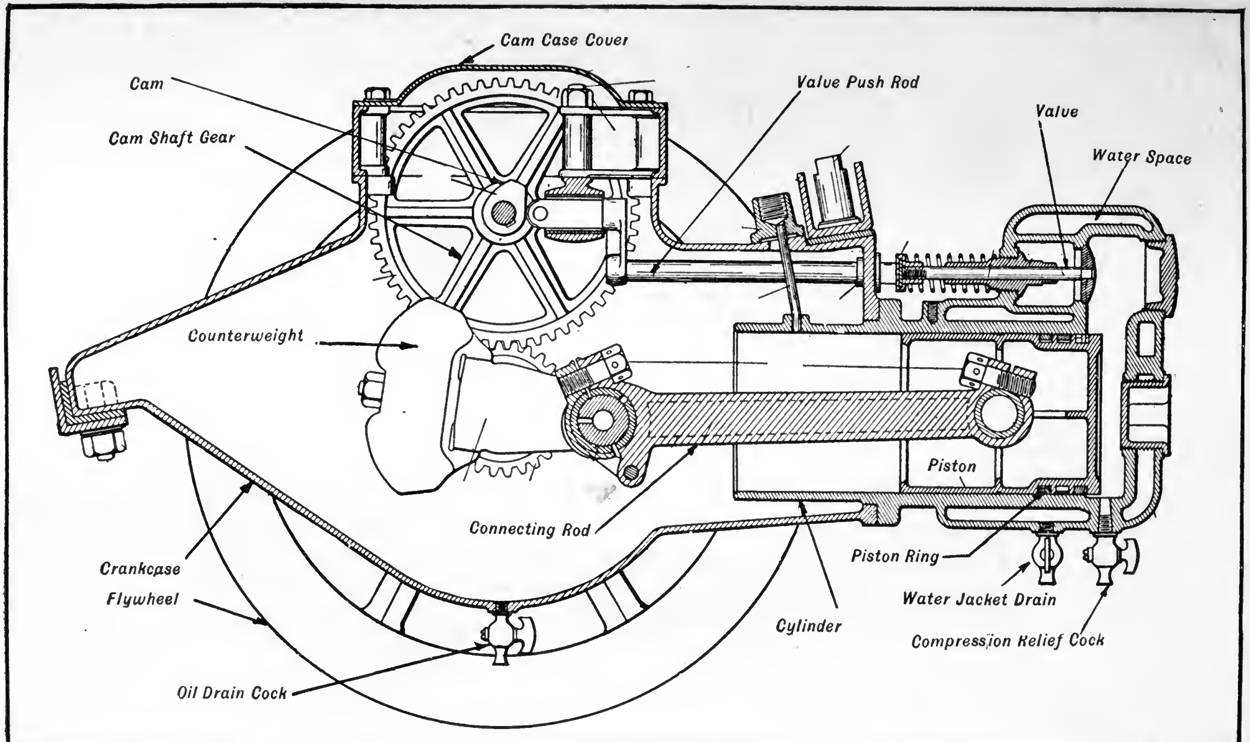


Fig. 33.—Sectional View One-Cylinder Horizontal Engine Used on Some Reo Models, a Type That Is Rapidly Being Replaced by Four-Cylinder Motors. These Motors Were Operated at Moderate Speed and Had Considerable Vibration if Speeded Up or Run Slowly.

all moving parts and cooling those portions liable to become excessively hot by suitable extraneous means.

Typical Single-Cylinder Engines Described.—The gasoline engine may have any number of cylinders, though the conventional types used in automobile propulsion seldom use any but an even number and rarely more than six. At one time single-cylinder motors were very popular. These were used in both the horizontal and vertical types. A typical form of horizontal motor is shown at Fig. 33. Power plants of this type were, for the most part, of low power and were patterned largely after stationary gasoline engine practice as far as proportion of parts was concerned. They were heavy and operated at low speed. Such engines are seldom employed at the present time, except in cars of ancient construction, many of which are still in use. Though this type of motor was comparatively slow acting and considerable vibration existed while it was in operation, they were strongly constructed and capable of giving very satisfactory service. Engines of this type are usually installed under the body, the engine cylinder being parallel with the frame side member while the crank shaft was at right angles to it. This permitted a very simple and efficient method of power transmission as the change speed gearing which was usually carried on the crank shaft extension could be easily coupled to the rear axle by means of a single chain and a pair of sprockets.

Owing to the vibration which obtains from the heavy explosion in the large single-cylinder engine other forms were evolved in which the cylinder was smaller and power obtained by running the engine faster. The single-cylinder motor of the vertical type is shown at Fig. 34. The pattern shown at Fig. 33 is distinctively of American derivation and was designed to avoid the rapid wearing and noisy acting single-cylinder motors of the foreign vertical type.

When a single-cylinder engine is employed a very heavy fly wheel is needed to carry the moving parts through idle strokes necessary to obtain a power impulse. For this reason modern designers prefer to use more than one cylinder, and the tendency is to produce power by frequently occurring light impulses rather than by a smaller number of explosions having greater force. When a single-cylinder motor is employed the construction is heavier than is needed with a multiple-cylinder form. Using two or more cylinders conduces to steady power generation and a lessening of vibration. Most modern motor cars employ four-cylinder engines because a power impulse may be secured twice every revolution of the crank shaft, or a total of four-power strokes during two revolutions. The parts are so arranged that while the charge of gas in one cylinder is exploding, those which come next in firing order are compressing, discharging the inert gases and drawing in a fresh charge respectively. When the power stroke is

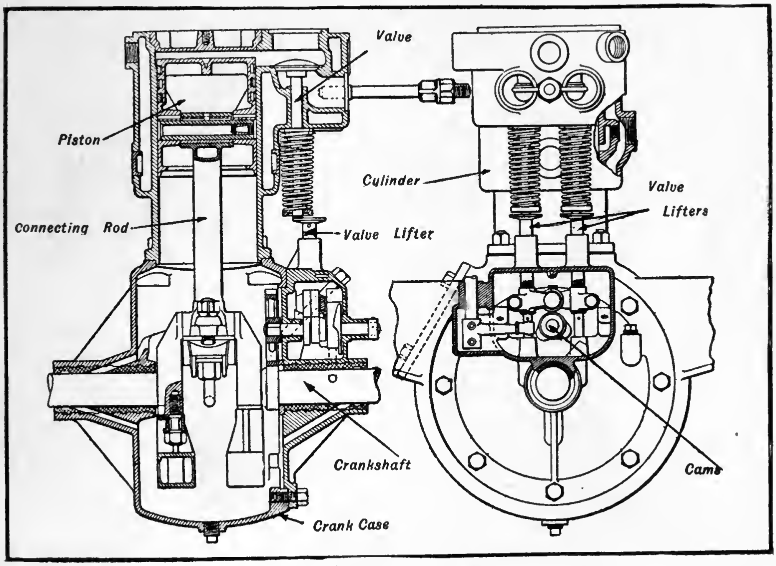


Fig. 34.—Sectional View of Brush Runabout Motor, a Simple Single-Cylinder Power Plant of the Vertical Type, Designed to Operate at High Speeds.

completed in one cylinder, the piston in that member in which a charge of gas has just been compressed has reached the top of its stroke and when the gas is exploded the piston is reciprocated and keeps the crank shaft turning. When a four-cylinder engine is used the fly wheel is much lighter than that of the single-cylinder form. In fact, many modern four-cylinder engines developing thirty horse power weigh less than the early single-cylinder forms which developed but one-third or one-fourth that amount of energy.

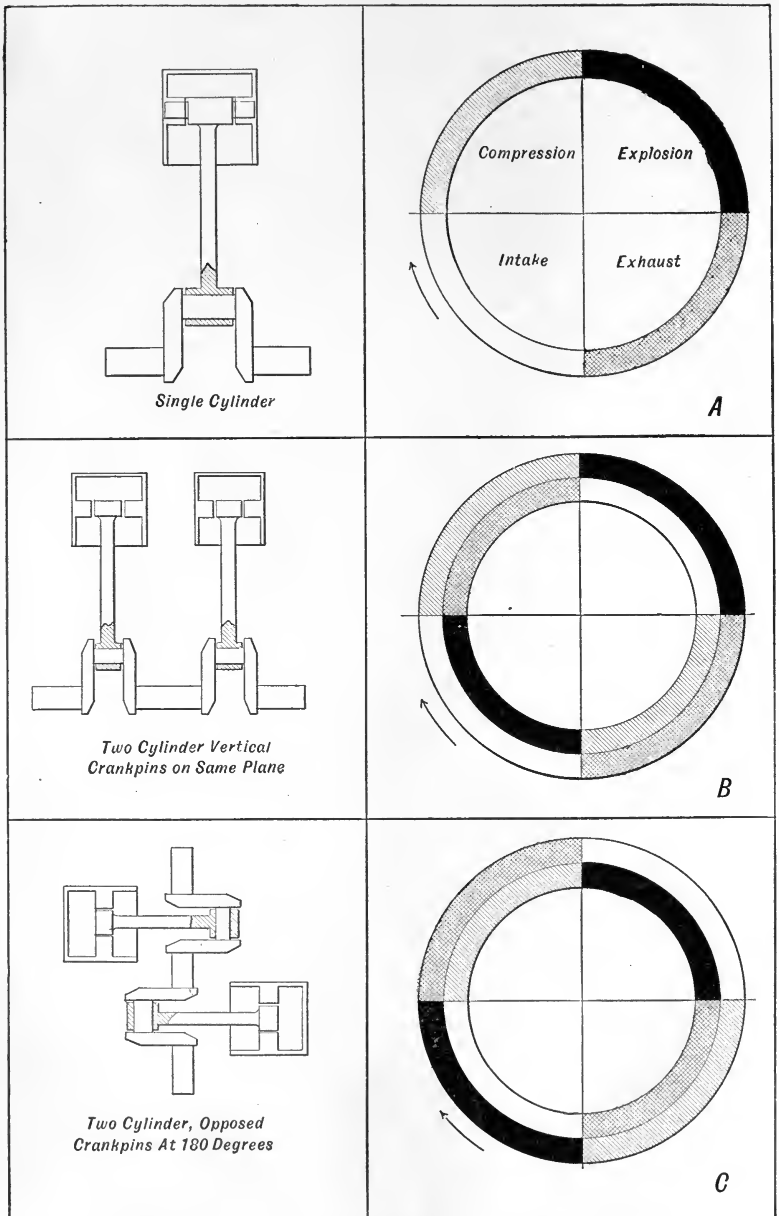


Fig. 35.—Diagrams Illustrating Sequence of Cycles in One- and Two-Cylinder Engines Show More Uniform Turning Effort on Crank Shaft with Two-Cylinder Motors.

Describing Sequence of Operations.—Referring to Fig. 35, A, the sequence of operation in a single-cylinder motor can be easily understood. Assuming that the crank shaft is turning in the direction of the arrow, it will be seen that the intake stroke comes first, then the compression, which is followed by the power impulse, and lastly the exhaust stroke. If two cylinders are used, it is possible to balance the explosions in such a way that one will occur each revolution. This is true with either one of two forms of four-cycle motors. At B, a two-cylinder vertical engine using a crank shaft in which the crank pins are on the same plane is shown. The two pistons move up and down simultaneously. Referring to the diagram describing the strokes, and assuming that the outer circle represents the cycle of operations in one cylinder while the inner circle represents the sequence of events in the other cylinder, while cylinder No. 1 is taking in a fresh charge of gas, cylinder No. 2 is exploding. When cylinder No. 1 is compressing, cylinder No. 2 is exhausting. During the time that the charge in cylinder No. 1 is exploded, cylinder No. 2 is being filled with fresh gas. While the exhaust gases are being discharged from cylinder No. 1, cylinder No. 2 is compressing the gas previously taken in.

The same condition obtains when the crank pins are arranged at one hundred and eighty degrees and the cylinders are opposed, as shown at C. The reason that the two-cylinder opposed motor is more popular than that having two vertical cylinders is that it is difficult to balance the construction shown at B, so that the vibration will not be excessive. The two-cylinder opposed motor has much less vibration than the other form, and as the explosions occur evenly and the motor is a simple one to construct, it has been very popular in the past on light cars.

To demonstrate very clearly the advantages of multiple-cylinder engines the diagrams at Fig. 36 have been prepared. At A, a three-cylinder motor, having crank pins at one hundred and twenty degrees, which means that they are spaced at thirds of the circle, we have a form of construction that gives a more even turning than that possible with a two-cylinder engine. Instead of one explosion per revolution of the crank shaft, one will obtain three explosions in two revolutions. The manner in which the explosion strokes occur and the manner they overlap strokes in the other cylinder is shown at A.

Assuming that the cylinders fire in the following order, first No. 1, then No. 3, and last No. 2, we will see that while cylinder No. 1, represented by the outer circle, is on the power stroke, cylinder No. 3 has completed the last two-thirds of its exhaust stroke and has started on its intake stroke. Cylinder No. 2, represented by the middle circle, during this same period has completed its intake stroke and two-thirds of its exhaust stroke. A study of the diagram will show that there is an appreciable lapse of time between each explosion.

In the four-cylinder engine operation which is shown at Fig. 36, B, it will be seen that the power strokes follow each other without loss of time, and one cylinder begins to fire and the piston moves down just as soon as the member ahead of it has completed its power stroke. In a four-cylinder motor, the crank pins are placed at one hundred and eighty degrees, or on the halves of the crank circle. The crank pins for cylinder No. 1 and No. 4 are on the same plane, while those for cylinders No. 2 and No. 3 also move in unison. The diagram describing sequence of operations in each cylinder is based on a firing order of one, two, four, three. The outer circle, as in previous instances, represents the cycle of operations in cylinder one. The next one toward the center, cylinder No. 2, the third circle represents the sequence of events in cylinder No. 3, while the inner circle outlines the strokes in cylinder four. The various cylinders are working as follows:

1.	2.	3.	4.
Explosion	Compression	Exhaust	Intake
Exhaust	Explosion	Intake	Compression
Intake	Exhaust	Compression	Explosion
Compression	Intake	Explosion	Exhaust

It will be obvious that regardless of the method of construction, or the number of cylinders employed, exactly the same number of parts must be used in each cylinder assembly and one can conveniently compare any multiple-cylinder power plant as a series of single-cylinder engines joined one behind the other and so coupled that one will deliver power and produce useful energy at the crank shaft where the other leaves off. The same fundamental laws governing the action of a single cylinder obtain when a number are employed, and the

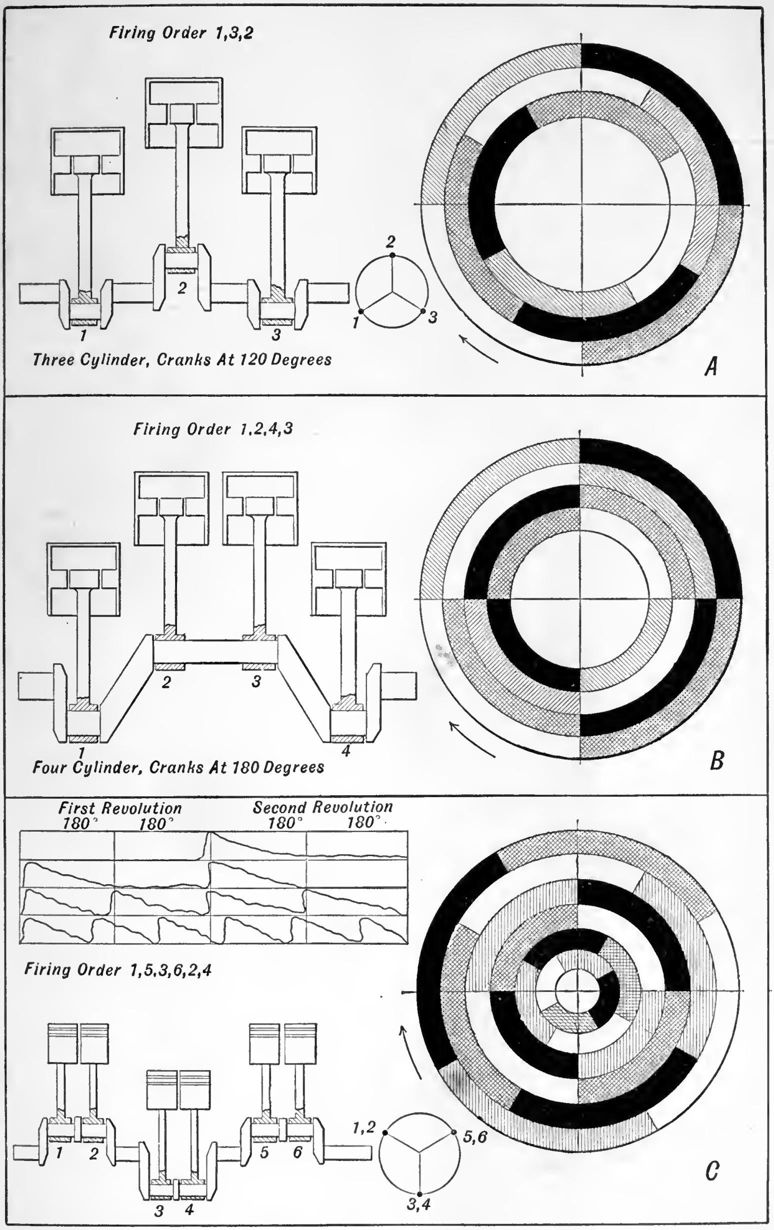


Fig. 36.—Diagrams Demonstrating Clearly Advantages which Obtain when Multiple-Cylinder Motors are Used as Power Plants.

sequence of operation is the same in all members, except that the necessary functions take place at different times. If, for instance, all the cylinders of a four-cylinder motor were fired at the same time, one would obtain the same effect as though a one-piston engine was used, which had a piston displacement equal to that of the four smaller members. As is the case with a single-cylinder engine the motor would be out of correct mechanical balance because all the connecting rods would be placed on crank pins that lie in the same plane. A very large fly wheel would be necessary to carry the piston through the idle strokes, and large balance weights would be fitted to the crank shaft in an effort to compensate for the weight of the four pistons, and thus reduce vibratory stresses which obtain when parts are not in correct balance.

There would be no advantage gained by using four cylinders in this manner, and there would be more loss of heat and more power consumed in friction than in a one-piston motor of the same capacity. This is the reason that when four cylinders are used the arrangement of crank pins is always as shown at Fig. 36, B—i. e., two pistons are up, while the other two are at the bottom of the stroke. With this construction, we have seen that it is possible to string out the explosions so that there will always be one cylinder applying power to the crank shaft. The explosions are spaced equally. The parts are in correct mechanical balance because two pistons are on the upstroke while the other two are descending. Care is taken to have one set of moving members weigh exactly the same as the other. With a four-cylinder engine one has correct balance and continuous application of energy. This insures a smoother running motor which has greater efficiency than the simpler one-, two-, and three-cylinder forms previously described. Eliminating the stresses which would obtain if we had an unbalanced mechanism and irregular power application makes for longer life. Obviously a large number of relatively light explosions will produce less wear and strain than would a lesser number of powerful ones. As the parts can be built lighter if the explosions are not heavy, the engine can be operated at higher rotative speeds than when large and cumbersome members are utilized.

The six-cylinder type of motor, the action of which is shown at Fig. 36, C, is superior to the four-cylinder, inasmuch as the power strokes overlap, and instead of having two explosions each revolution we have three explosions. The conventional crank-shaft arrangement with a six-cylinder engine is just the same as though one employed a three-cylinder crank shaft, having very wide crank pins so that the two connecting rods are joined to each crank throw. With the cranks arranged as outlined at Fig. 36, C, the firing order is one, five, three, six, two, four. The manner in which the power strokes overlap is clearly shown in the diagram. An interesting comparison is also made in the small diagram in the upper left-hand corner of this view.

A rectangle is divided into four columns; each of these correspond to one hundred and eighty degrees, or half a revolution. Thus the first revolution of the crank shaft is represented by the first two columns, while the second revolution is represented by the last two. Taking the portion of the diagram which shows the power impulse in a one-cylinder engine, we see that during the first revolution there has been no power impulse. During the first half of the second revolution, however, an explosion takes place and a power impulse is obtained. The last portion of the second revolution is devoted to exhausting the burned gases, so that there are three idle strokes and but one power stroke. The effect when two cylinders are employed is shown immediately below.

Here we have one explosion during the first half of the first revolution in one cylinder and another during the first half of the second revolution in the other cylinder. With a four-cylinder engine there is an explosion each half revolution, while in a six-cylinder engine there is one and one-half explosions during each revolution. When six cylinders are used there is no lapse of time between power impulses, as these overlap and a continuous and smooth-turning movement is imparted to the crank shaft. While the six-cylinder engine has obvious advantages, it will be evident that it must be fifty per cent more complicated than the four-cylinder, and as one obtains a smooth-acting engine with the lesser number, the majority of engineers favor the four-cylinder type of power plant for general service.

Actual Duration of Different Strokes.—In the diagrams presented at Figs. 35 and 36, the writer has assumed, for the sake of simplicity, that each stroke takes place during half of one revolution of the crank shaft, which corresponds to a crank-pin travel of one hundred and eighty degrees. The actual duration of these strokes is somewhat different. For example, the inlet stroke is usually a trifle more than a half revolution, and the exhaust is always considerably more. The

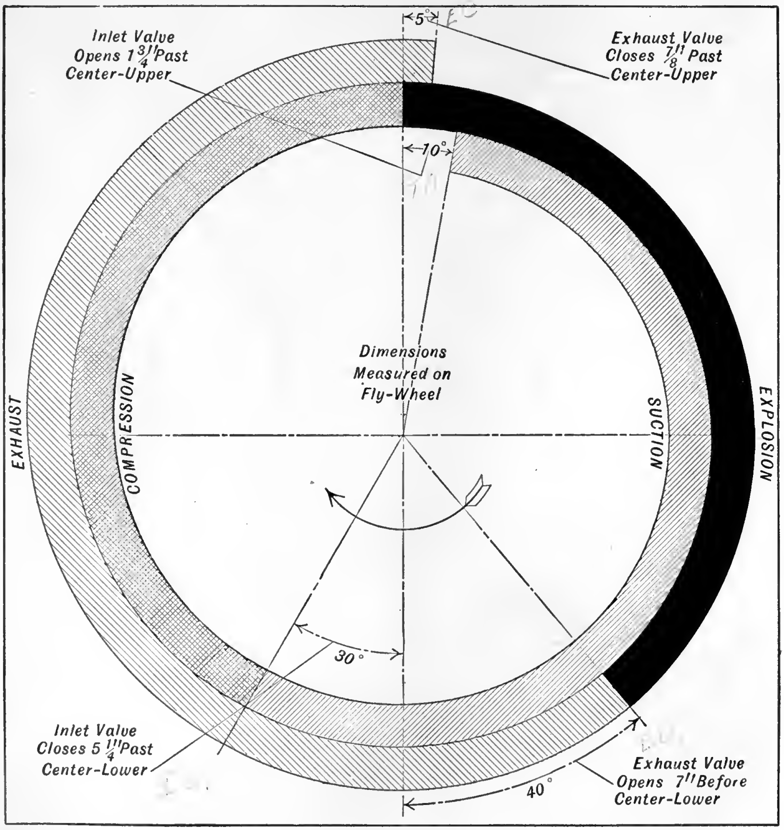


Fig. 37.—Diagram Showing Actual Duration of Different Strokes in Degrees.

diagram showing the comparative duration of the strokes is shown at Fig. 37. The inlet valve opens ten degrees after the piston starts to go down and remains open thirty degrees after the piston has reached the top of its stroke. This means that the suction stroke corresponds to a crank-pin travel of two hundred degrees, while the compression stroke is measured by a movement of but one hundred and sixty degrees. It is common practice to open the exhaust valve before the piston reaches the end of the power stroke so that the actual duration of the power stroke is about one hundred and forty degrees, while the exhaust stroke corresponds to a crank-pin travel of two hundred and twenty-five degrees. In this diagram, which represents proper time for the valves to open and close, the dimensions in inches given are measured on the fly wheel and apply only to the "Model M" Thomas motor. If the fly wheel were smaller ten degrees would take up less than the dimensions given, while if the fly wheel was larger a greater space on its circumference would represent the same crank-pin travel.

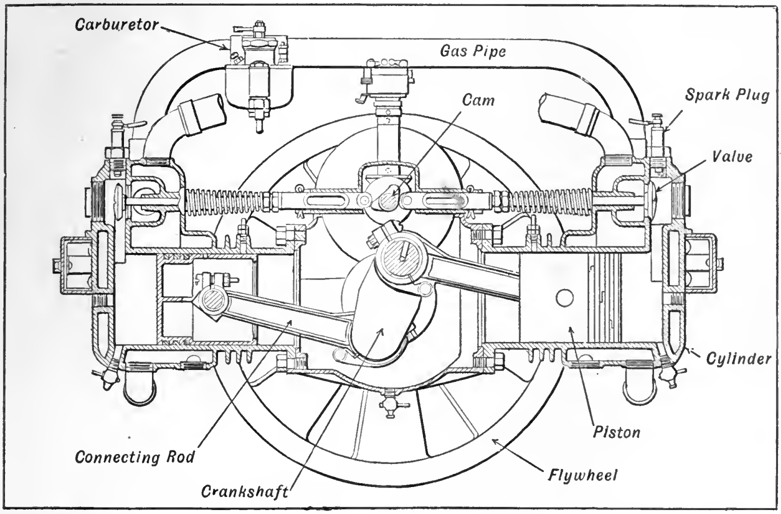


Fig. 38.—Simple Form of Two-Cylinder Motor Having Opposed Cylinders; a Very Popular Form of Power Plant for Light Service.

Typical Engine Types Described.—A very simple and efficient type of power plant is shown at Fig. 38. In this motor the cylinders are horizontally disposed and opposed to each other. The valves are carried in a pocket, or chamber, on top of the cylinder and they are operated by direct push-rod movement from a cam shaft carried just above the crank shaft. The general arrangement of parts is clearly outlined, and as each component is indicated there should be no difficulty in grasping the details of this form of power plant. The motor illustrated at Fig. 39 is a simple four-cylinder type of modern construction and may be considered representative of standard practice. In this motor it will be seen that the four cylinders are arranged on a crank case common to them all. The crank case also acts as a supporting member for the crank shaft and cam shaft. A section of the crank case is broken away to show the crank-shaft design, and also to illustrate the method employed of raising the valves from their

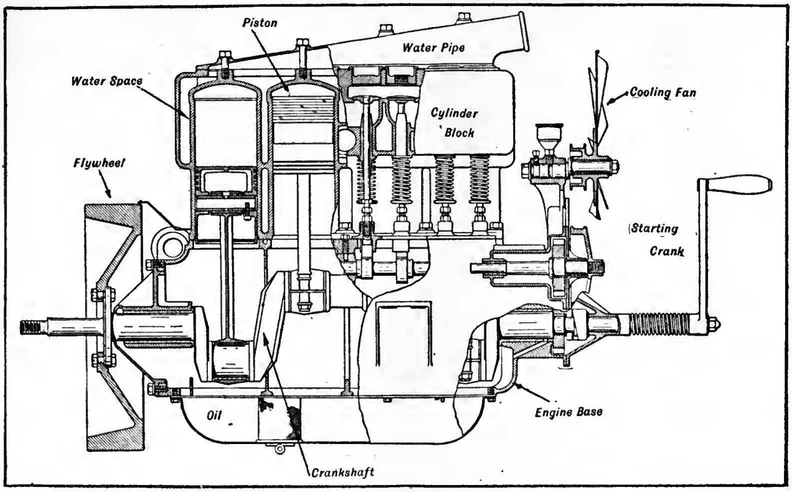


Fig. 39.—Sectional View of Four-Cylinder Motor, the Most Widely Used Type of Multiple Engine.

seats by means of cams. The front cylinder is not sectioned. The second cylinder, which is immediately back of it, is sectioned through the valve chest in order to show the gas passages and the method of closing them by mushroom valves. Cylinder No. 3 is divided on its center line to show the piston and connecting rod assembly, while the last cylinder is sectioned in such a way that the construction of the piston, connecting rod, and wrist pin is clearly shown.

Another type of four-cylinder engine sectioned in a somewhat similar manner with all parts indicated is shown at Fig. 40. A

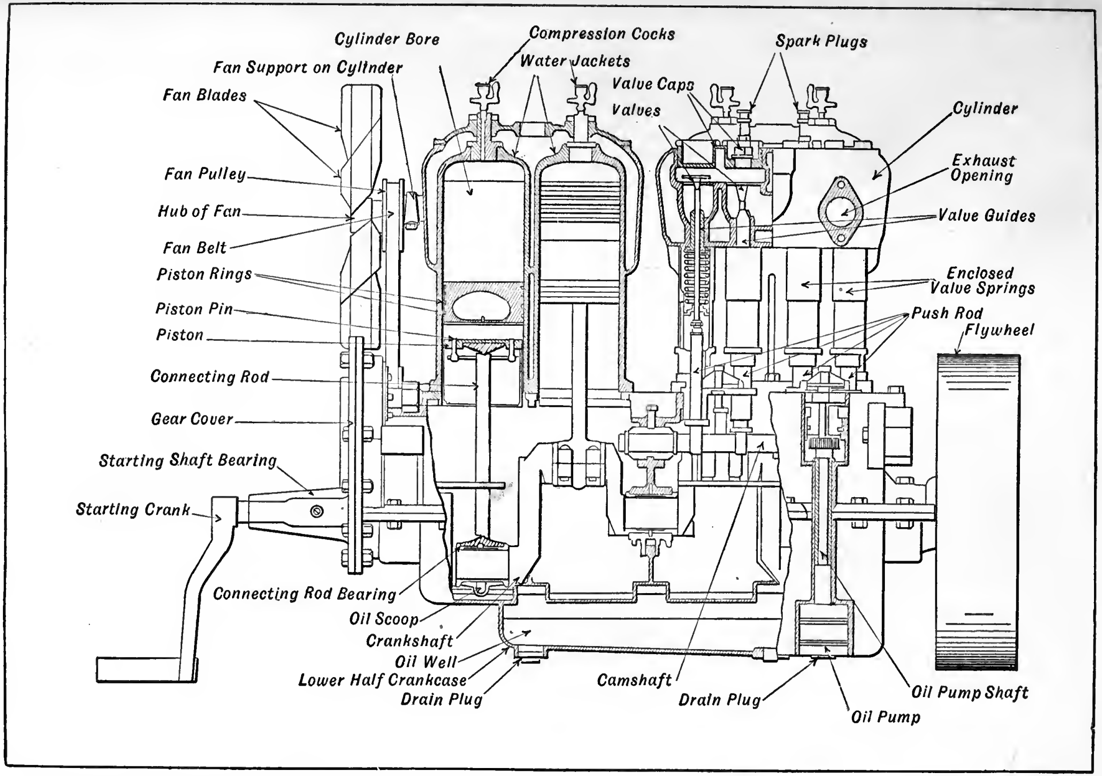


Fig. 40.—Sectional View of Typical Four-Cylinder Cycle, Four-Cylinder Engine, Showing Important Internal Components and their Relation to Each Other.

careful study of this illustration should familiarize one with the general arrangement of the parts of conventional power plants. The views shown at Figs. 39 and 40 are longitudinal sections. In order

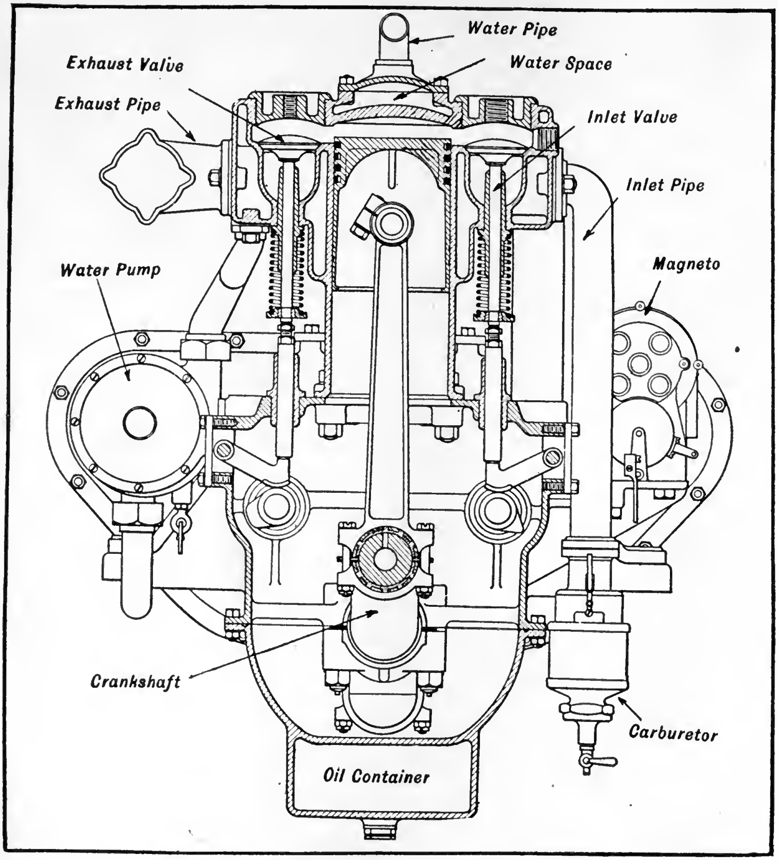


Fig. 41.—Sectional View of Rear Cylinder of Gasoline Engine with Important Parts Indicated.

to show the appearance of the parts of an engine when one of the cylinders is cut in such a manner that it is viewed from the end rather than from the side, such a section is given at Fig. 41. As is the case in other illustrations all parts are clearly indicated. This view is also valuable in showing the arrangement of some of the auxiliary components, such as the water pump, which is used to circulate the cooling liquid; the carburetor, which is employed to furnish the explosive mixture; and the magneto, which is supplied to ignite the compressed gas. The exhaust pipe, which is attached to the side of the cylinder to carry away the burned gases, and the sump, or oil container, which carries a supply of the lubricant to keep the working surfaces free, are also outlined.

Features of the Knight Slide Valve Motor.—One of the latest tendencies of engineers responsible for the design of motor-car power plants is toward the elimination of all noises incidental to their operation. Much of this has been attributed to operation of the valves and in order to reduce the clatter, types of engines in which the poppet, or mushroom, valves are replaced by sliding or revolving elements are being extensively experimented with.

The earliest types of explosion motors, as evolved by Lenoir, Brayton, and Otto, employed simple slide valves which were patterned after those used in steam engines. Owing to faulty construction these early forms were not successful, as considerable difficulty was experienced from warping and in keeping the cylinder tight enough to retain gas pressure. In several engines of recent development the mushroom valves are being replaced by sleeves which have a more gradual motion and which slide by ports in the cylinder instead of being brought forcibly in contact with the seats by a strong spring. An advantage of the slide valve motor, which is perhaps even more important than that of silence, is the increased flexibility and augmented power developed, because the large gas passages permit the entering stream of fresh vapor, or the departing current of inert gas to leave the cylinder without being impeded. The disadvantage often cited against poppet valves is that at high speeds they fail to follow the contour of their actuating cams accurately and there is considerable loss of power because of the irregular gas flow.

The most practical and satisfactory of the valveless motors now in use was invented by Charles Y. Knight, an American engineer, several years ago. When first introduced in this country it was met with considerable ridicule, and the inventor was forced to take his invention to Europe, where its advantages met with prompt recognition.

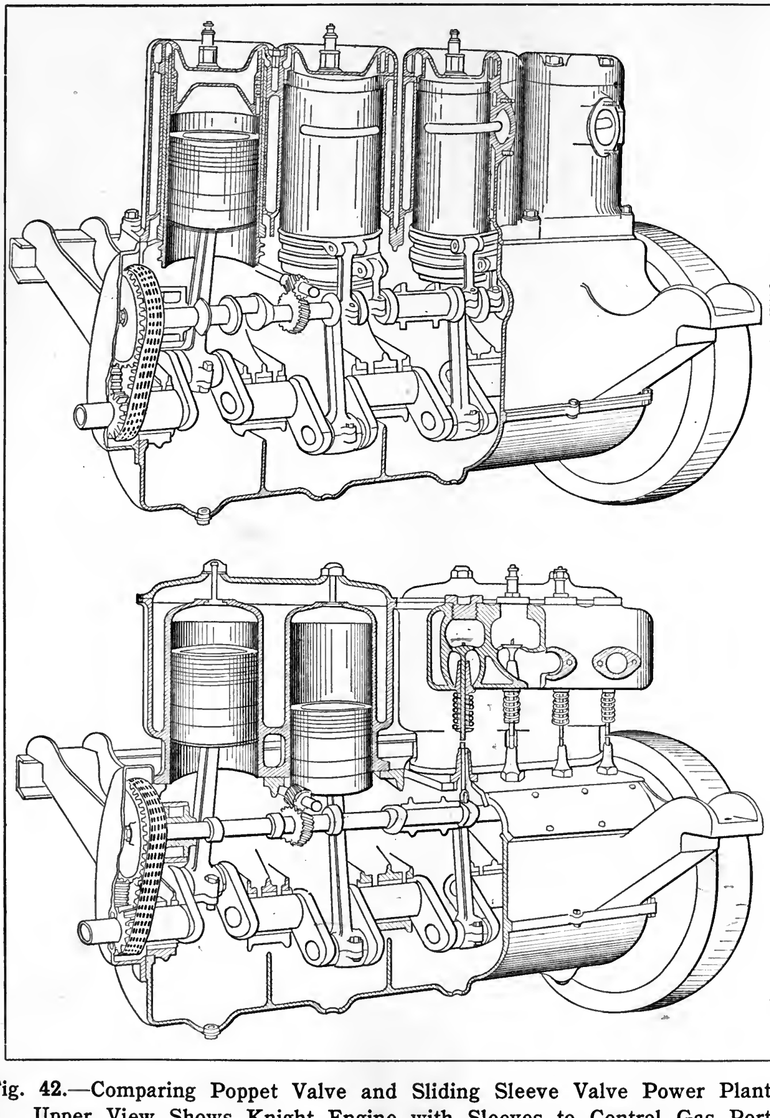


Fig. 42.—Comparing Poppet Valve and Sliding Sleeve Valve Power Plants. Upper View Shows Knight Engine with Sleeves to Control Gas Ports. Lower Illustration Shows Gas Passages Controlled by Mushroom Valves.

The Knight valveless motor is now made and used by such celebrated automobile manufacturers as, Daimler, in England; Panhard-Levassor, in France; Minerva, in Belgium; and Mercedes, in Germany. In this country it will be found on models of the Columbia, Stearns, and Stoddard-Dayton.

The operating principles in this engine do not differ materially from other four-cylinder, four-cycle types, the only difference being in the method of admitting and expelling gases from the cylinder. The illustrations at Fig. 42 show very clearly the difference which exists between the slide valve and the conventional poppet valve motor. Both of these are the same in general design, except that changes have been made in the power plant to permit the use of reciprocating sleeves. The upper illustration represents the slide valve motor in part section, while the lower view shows the conventional poppet valve type.

The Knight motor has four cylinders cast in pairs. The top of each cylinder has two lateral slots which communicate respectively with the inlet and exhaust pipes. The cylinder is water-jacketed, and inside of this member and interposed between it and the piston are two thin, hollow cast-iron cylinders, or sleeves, adapted to be moved up and down by a suitable crank shaft and connecting rod mechanism or eccentrics. These sleeves have large ports which communicate with the orifices in the cylinder wall. They are moved in such a manner that the slots in the cylinder are opened and closed by the reciprocating movement of the sleeves. They are operated by small connecting rods which work from a smaller crank shaft mounted to one side of, and above the main crank shaft, and driven by silent chain gearing. The travel of the sleeves is comparatively small, as their velocity is but one-tenth that of the piston. The openings in the sleeves are so wide that the gases enter and leave the combustion chamber much more easily than they could through ports closed by valves of the conventional type.

The movement of the sleeves is such that the ports in the cylinder are closed by one or both sleeves during three-quarters of the cycle of operation, and are kept open during the remaining quarter by a simultaneous lining up of the openings in both sleeves with that in the cylinder. As is the case with a four-cycle motor of the conven-

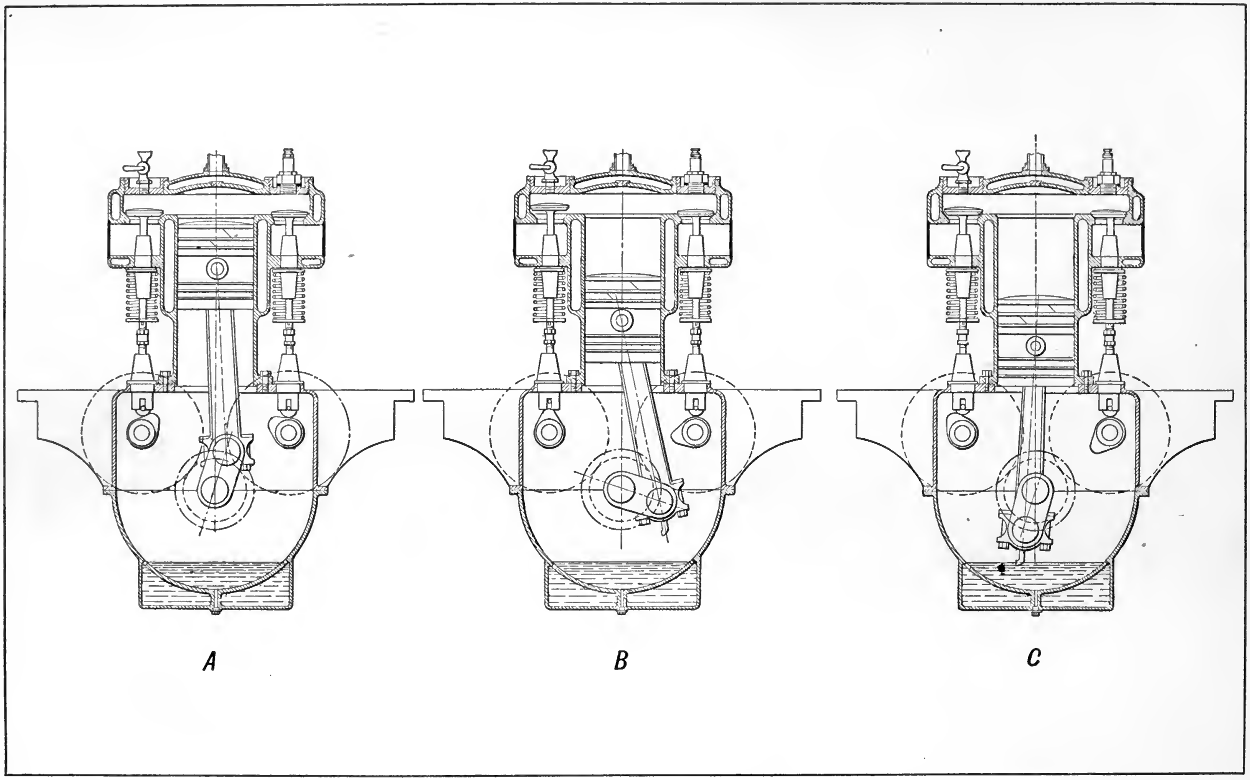


Fig. 43.—Showing Action of Inlet Valve and Cam of Conventional Type. Note Gradual Valve Opening, which Does Not Attain its Full Value for Some Time.

tional pattern during the first downstroke of the piston the inlet port is opened and the exhaust orifice closed. During the next two piston strokes, one up and the other down, corresponding to the compression and explosion of the gas, both ports are kept closed. Then during the last upstroke, which corresponds to the scavenging period, the exhaust port is opened and the inlet port closed.

It is claimed that this motor is very silent at high speeds, and it is more flexible in operation than other forms. It is also said that this type of motor will retain its compression longer than the poppet valve type, because there can be no escape of gas through the ports when they are closed by the sleeves. The moving members are lubricated in the usual manner, the only precaution taken being to insure an even distribution of oil by cutting a spiral groove and boring a number of holes in each sleeve. The great advantage of this type over the poppet valve motor can be very well shown by comparing the illustrations at Figs. 43 and 44, which show action of the valves used on the ordinary motor with the views at Figs. 46 and 47. At Fig. 43, A, the position of the piston, crank shaft, cam, and intake valve are shown at the beginning of the charging stroke. It will be noticed that the intake valve has just barely left its seat and that there will be little space for the gases to flow into the cylinder until the piston has reached the position shown at Fig. 43, B, at which point the inlet valve is fully opened. From this point to that outlined at Fig. 43, C, the inlet valve closes and the gas passage becomes more and more restricted as the piston travels down. The same condition obtains when the exhaust valve is operated. It lifts gradually, and the full opening is not attained until the parts have assumed the position shown at Fig. 44, B. From this point to that outlined at Fig. 44, C, the valve is closing. It will be evident that with mushroom valves one attains the maximum port opening only during the time that the cam follower rides on the point of the cam which is but an instant. The cam roller follows the cam profile only at low and moderate speeds. When the velocity increases the cam will throw the push rod instead of lifting it and the action will be erratic. Incidentally, these views show very clearly the method of valve operation and will prove valuable in assisting the reader to gain an idea of valve timing which will be discussed at length in proper sequence.

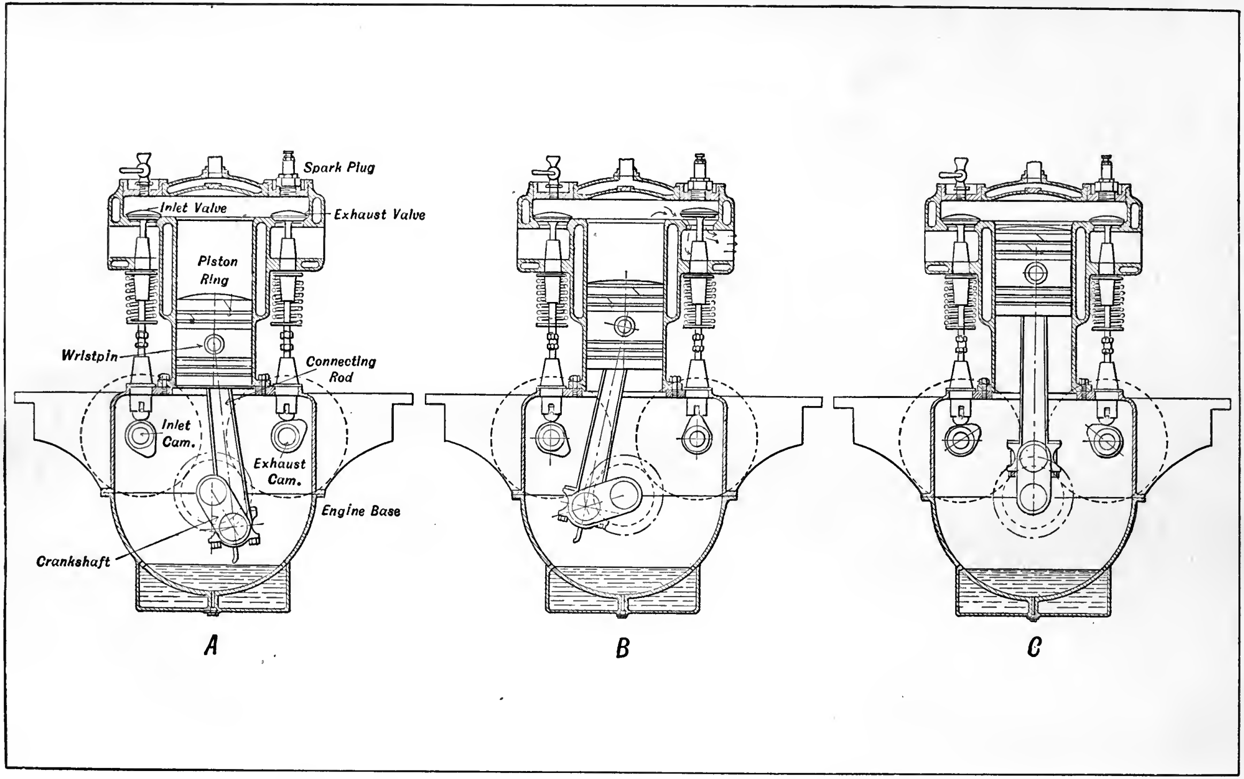


Fig. 44.—Showing Action of Exhaust Valve of Conventional Motor Type.

The view at Fig. 45 is a simplified section which shows the parts of the Knight type motor to advantage. The diagrams at Figs. 46 and 47 will enable the reader to see the relation of the sleeves at different points in the cycle of operation. At Fig. 46, A, the position at the inception of the intake stroke is clearly shown. At B the parts have assumed positions that permit the fresh gas to flow quickly into the cylinder. At C the sleeves are closed. It will be apparent that one obtains a clear port through which the gases may flow easily as soon as the intake stroke begins. This is increased in value until the maximum opening is reached, just as with a poppet valve. The important point to observe, however, is that there is always a straight passage for the gas to flow through while the port is open. Even when the poppet valve has been raised to the highest point there is still difficulty for the gas to leave the cylinder because of the tortuous passage and the number of turns the gas stream must make to enter and leave the combustion chamber. Fig. 47 depicts the movement of the sliding sleeve valves on the exhaust stroke.

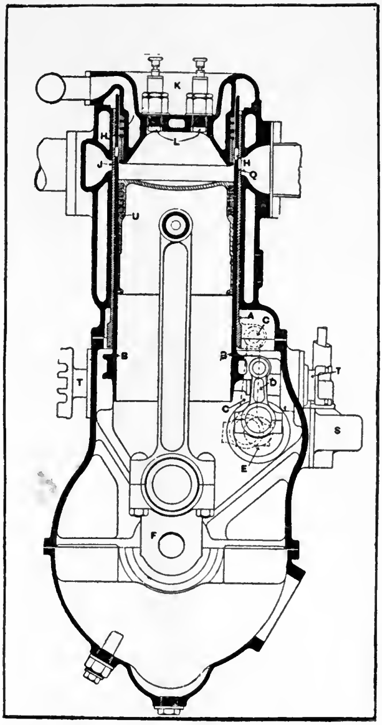


Fig. 45.—End Sectional View of Knight Sliding Sleeve Type Motor, Showing Sleeves which Take Place of the Poppet Valves of Conventional Motors. A—Outer Valve Shell. B—Inner Valve Shell. C—Operating Lever for A. D—Operating Lever for B. E—Lay Shaft. F—Crank Shaft. G — Helical Gears. H — Valve Opening. K—Cylinder Head. L — Sparking Plug Holes. O — Cross - Shaft Driving Pump and Magneto. U—Piston.

In order to obtain uniform power application and a smooth running engine it is essential that the gases in each cylinder be compressed to the same value before ignition takes place. If the compression is less in one cylinder then that member will be doing less work than the others and the rotative speed will not be constant. The crank shaft will slow up when it comes to the weak cylinder, and will accelerate when the three strong ones are acting on it. It is claimed that in the Knight motor the absolute constancy of compression makes for uniformity of action because the intervals between the successive explosions are always equal and all of the power strokes have the same strength. It is also advanced that the construction of the Knight motor makes it possible to obtain combustion chambers which are equal in volume, which condition is difficult to attain with the ordinary construction, because of the difficulty met in securing perfect equality of castings. As the cylinders and cylinder heads of the Knight motor are machined to the required dimensions and polished, all combustion chambers will have the same volume. Another advantage is that there will be no projecting particles of metal such as would be present in castings that might remain hot and cause premature explosions. It is also difficult for carbon to adhere to the absolutely smooth walls of the combustion chamber or piston head.

There is very little strain on the parts, and as the wear of the sleeves is negligible the motor action improves with service, because the sleeves become polished and work easier the more they are used. As the sleeves are driven by cranks and connecting rods and not by cams as poppet valves are, they are not liable to go wild at even the highest motor speeds. The ports are opened and closed exactly at the proper time, and the openings or passages for the gas are so large that the motor capacity augments with an increase of speed.

In a comparative test of two similar motors, one with mushroom valves and the other with sleeves, the former developed but twenty-five horse power at 2,000 revolutions per minute, while the sleeve type generated in excess of thirty horse power under the same conditions. The Knight motor has been subjected to severe tests before adoption in comparison with motors of the poppet valve type. In one of these an engine rated at thirty-eight horse power which had cylinders of 5-inch bore and stroke developed 55.3 horse power continuously during a period of 5½ days, or 132 hours. The fuel consumption was but 0.85 pint of gasoline per horse power hour. The average fuel consumption of the four-cycle type of motor is placed at one pint per horse power hour. At the completion of this running in test the power plant was installed in a car weighing 4,000 pounds. This was driven over 2,000 miles on Brooklands Motor Track, near London, England, at a speed which averaged forty-three miles per hour. At the completion of this test the motor was replaced on a test stand in the shop where it developed an average of 57.25 horse power during a run of five hours at 1,200 revolutions per minute. The fuel consumption was reduced to 0.75 pint of gasoline per horse power hour and it had gained two horse power, or about four per cent by use.

This type of valveless motor is considered to be an improvement over the conventional forms, and it is all the more strange when one considers that the height of its development has been reached at a time when all believed the explosion motor had attained its maximum efficiency. The success attending the use of the Knight motor has promoted great interest in all forms of valveless motors which are being actively experimented with at the present time. Some of the most successful of these types will be described in detail in the following chapters.

Operating Principles of Two-Cycle Engines.—While the majority of automobiles use four-cycle internal combustion engines for propulsion there are cases where the simpler two-stroke cycle motor has been used. Though it has been widely used in marine applications for years it has not become very popular in motor-car service. If considered from a theoretical point of view the two-cycle engine has important advantages, and if ideal conditions were obtained in practice, motors of this type would develop twice the amount of power obtainable from four-cycle engines having the same number of cylinders, equal piston displacement and operating at the same crank shaft speed.

The two-cycle motor is much simpler than the other forms, and it has but three moving ports per cylinder. In this type a power impulse is obtained with each downstroke of the piston instead of every other downstroke. With the explosion occurring twice as often the energy delivered is increased in direct proportion and a more even turning movement of the crank shaft results because of the more rapid series of explosions. It has been shown that with the four-stroke engine three operations are necessary to obtain a useful power impulse. The first downward movement of the piston draws in the gas. The following upward movement compresses the mixture. The second down movement of the piston takes place during the expansion or explosion stroke, and is the third and power-producing part of the cycle. Following this operation the remaining stroke of the piston, which is upward, clears the cylinder of burned gas.

Obviously all the work is done at the top of the piston, and the differing functions take place in the combustion chamber or that portion of the cylinder above the piston. With a two-cycle engine all this work can be accomplished in half the number of strokes, and it is possible to secure an explosion stroke after each idle stroke. There is a power impulse every revolution of the crank shaft for each cylinder instead of every two turns, and energy is created every two strokes of the piston. To accomplish this, work is performed on both sides of the piston, as the crank case is utilized as well as the part of the cylinder above the piston. The top of this member compresses the charge and receives the pressure of the explosion, as these two essential functions can only take place in that portion of the cylinder above the piston. The crank case performs the duty of the inspiration stroke, as the mixture is drawn into the engine base by the upwardly moving piston. This is done at the same time that the piston is moving up to compress the gas above it, previously taken in. The views at Fig. 48 show the principles of operation of two-port, two-cycle engines, while those at Fig. 49 define the fundamentals of three-port two-cycle engine operation. The principle in the main is the same for both types, the only difference being in the method of introducing the gas to the crank case.

It will be seen that such engines are very simple, and that the pistons, connecting rods, and crank shaft are the only moving parts. Instead of valves and operating mechanism to control the gas flow by ports, or passages which are cast in the cylinder walls about halfway down their length are used. The gas is taken into the engine base, which is air tight, and of small capacity; in one case through an automatic check valve fitting to which the carburetor is attached. In the three-port form this valve is eliminated and the carburetor is coupled

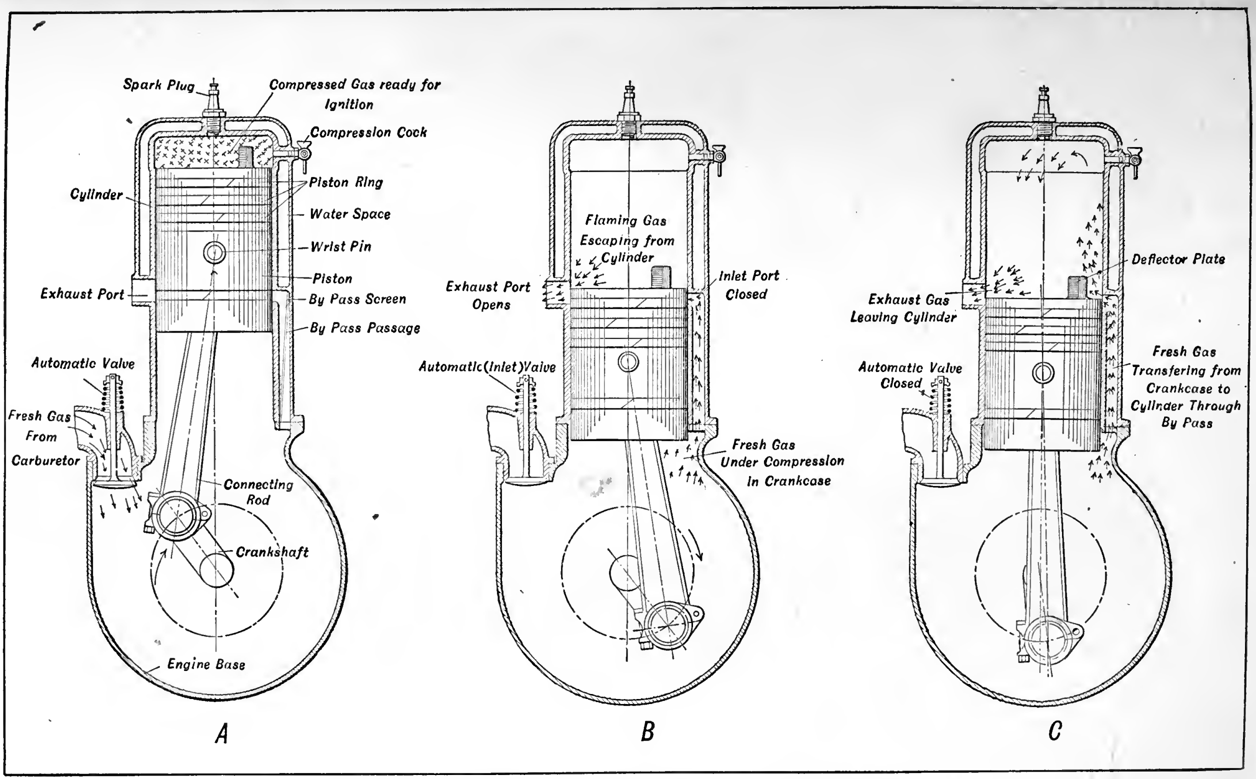


Fig. 48.—Defining Two-Port, Two-Cycle Engine Action.

directly to the cylinder. The gas is transferred from the crank case to the cylinder through a bypass, or a passage leading from the engine base to the intake port.

Considering first the action of the two-port, two-cycle type it will be evident that if the base is air tight an upward movement of the piston will produce a suction in the engine base, drawing the inlet valve down from its seat and inspiring a mixture of gasoline and air from the carburetor. Thus when the piston moves up, the engine base fills with vapor. On the down movement of the piston the gas in the crank case is compressed, and when the top of the piston registers with the inlet port in the side of the cylinder the mixture will transfer to the cylinder above the piston because of its pressure. The intake port is opened as the piston side uncovers it. The compression in the engine base is light compared to that above the piston. While the compression pressure before ignition may be as high as eighty pounds per square inch, that in the engine base necessary to insure prompt transfer of the charge seldom exceeds ten pounds. The operation of this type engine is not difficult to understand.

Referring to Fig. 48, A, we will assume that there is a compressed charge of gas above the top of the piston, and that the crank case is full of mixture. The spark occurs at the spark plug and the resulting explosion forces the piston down on its power stroke, this movement also compressing the gas already in the engine base. When the piston uncovers the exhaust port it begins to open before the intake port is uncovered and the burned gases escape to the air because of their pressure. After the exhaust port has been open for a small period the inlet port is uncovered by the piston which is still on its downward movement. The compressed gas in the case flows through the bypass and into the cylinder. It cannot escape out of the open exhaust port opposite, because the deflector directs the gases toward the top of the cylinder. The fresh gas coming in tends to force out any of the burned residue which tends to remain. As the piston rises on the return stroke both ports are closed and the gas in the cylinder is compressed. Simultaneously with the gas compression the partial vacuum created in the engine base draws in new mixture from the carburetor through the open check valve.

Three-port engine operation, as shown at Fig. 49, is very similar

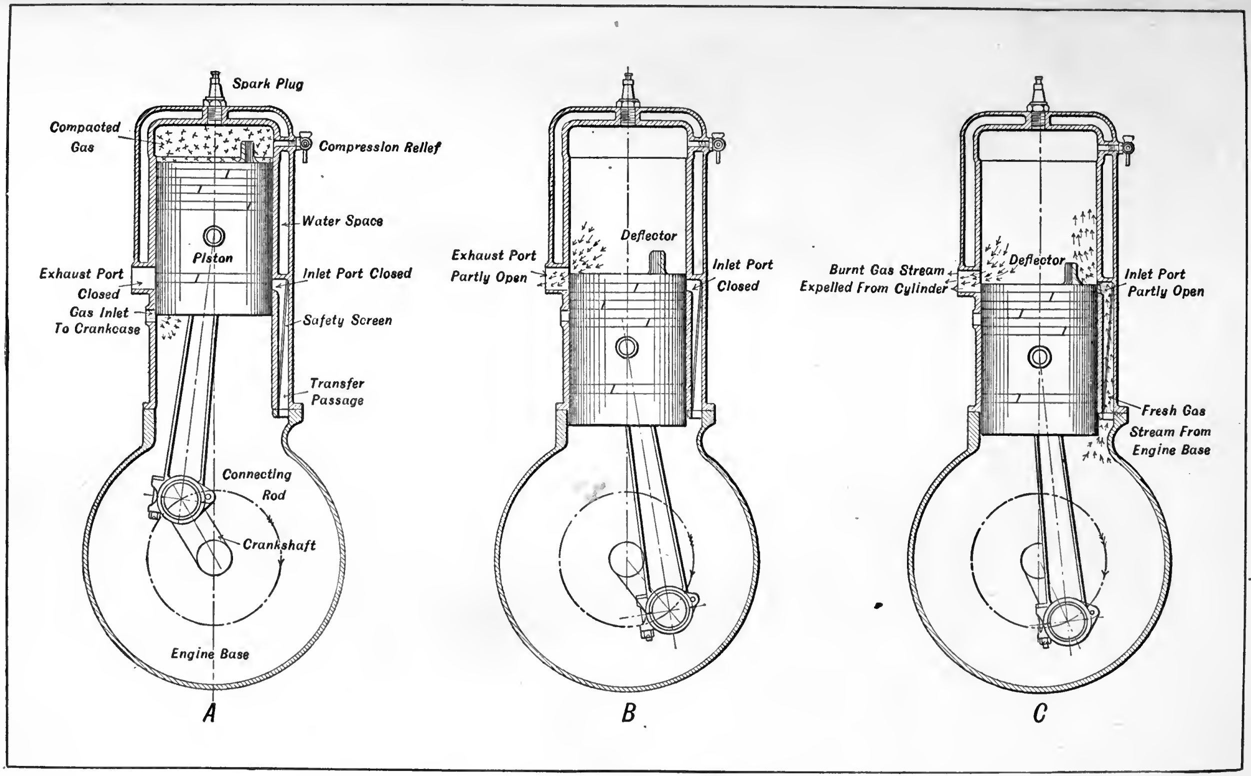


Fig. 49.—Showing Three-Port, Two-Cycle Engine Operation.

to that previously described, except that the intake port in the cylinder to which the carburetor is coupled is uncovered by the piston only when it has traveled up in the cylinder. There is a pronounced vacuum in the crank case when this port is uncovered and the rapid rush of gas insures quick charging. The three-port engine is considerably faster than the two-port type, and is more popular for motor-car service. In the three-port form of engine the mixture rushes in to fill the engine base as a body, whereas in the two-port type it is drawn in gradually during the whole upstroke of the piston.

If the reader compares the views of the simple two-cycle engines shown, with the four-cycle types previously described, it will be seen that the former are simpler, because many of the small parts necessary for the successful action of a four-stroke motor are not needed in the two-stroke motor. The valves and operating mechanism are dispensed with, which means elimination of the cam shafts, driving gearing, cams, and push rods, incidental to valve operation. As the cylinder of the two-cycle engine is charged and cleaned through simple ports which are but orifices left after cutting away part of the cylinder wall, the gas can be introduced and discharged with much less mechanism. The ports are covered by the piston until the time comes when they are needed. In the two-port form both openings are opened fully only when the piston reaches the end of the downstroke, but in the three-port motor the remaining opening through which the crank case is charged is uncovered when the piston reaches the end of its upward movement.

The simple forms of two-cycle motors described have been replaced in some cases by types in which the preliminary compression of gas in the crank case has been eliminated. This is accomplished by the use of a two-diameter piston, as shown at Fig. 50. The cylinder proper consists of an upper and lower chamber. The small portion of the piston fits the upper cylinder while the enlarged part fits the lower end. Instead of the gas being inspired into the engine base it is drawn into the enlarged portion of the cylinder. It has been difficult to maintain regularity of two-cycle motor action when crank case compression was used, because any leakage at the bearings, or packings in the crank case, meant a reduction in vacuum and made for uncertain charging.

With the construction outlined at Fig. 50, the gas is taken into the large portion of the main cylinder, and as the pumping piston is provided with packing rings just as the working piston is, it is not difficult to keep a tight charging chamber. The positions of the pistons in the various cylinders of a four-cylinder motor using a differential piston arrangement are shown at Fig. 50. It will be seen that a rotary distributing valve must be used to permit the gas to enter the pump cylinder and flow into the working cylinder at the right time; this is turned by gearing from the crank shaft.

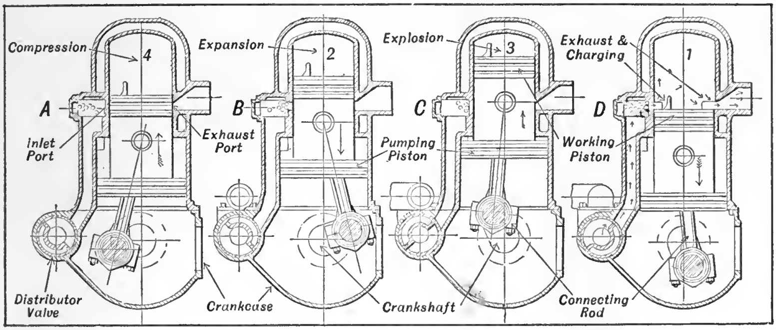


Fig. 50.—Explaining Action of Differential Piston Type of Two-Cycle Engine.

At A the piston is going up and a charge of gas is being compressed in both the working cylinder and the pump cylinder. At B, which represents the section through cylinder No. 2, the piston is moving down under the influence of the explosion and the pumping piston is drawing in a charge of gas through the distributing valve which is in communication with the inlet pipe. At C a section through cylinder No. 3 is shown. The working piston in this case has reached the top of its stroke and is ready to receive the impact due to the explosion of the charge. At D a section through cylinder No. 1 is outlined. The cylinder valve has made communication with the pumping chamber of cylinder No. 3, as shown at C, and a charge of gas is being transferred to the working cylinder No. 1. The burned gases are expelled through the open exhaust port in the usual manner and admitted by the customary intake port adjacent to the deflector plate. The action in this type of engine may be easily understood if one considers that the pumping chamber of one cylinder is employed to draw in gas and compress it prior to transferring it to the working chamber of another cylinder.

Why Two-Cycle Motor is not Widely Used.—It has been previously stated that the four-cycle motor is almost universally used, and to properly understand the reason for the preponderance of this type over the simpler two-cycle forms it is necessary to compare the actual results obtained from the two-stroke motor in ordinary practice with the advantages a purely theoretical consideration will give it. There are a number of problems to be solved before the two-cycle motor will compare with the other type in efficiency. To obtain maximum power it is necessary that a full charge of explosive gas enter the cylinder; that this mixture must be properly proportioned; that it should be compacted to a certain point before ignition, and that it must be ignited promptly and at the proper time. In order to obtain a full charge of pure mixture it is evident that the exhaust gases must be entirely expelled from the cylinder in order that the incoming fresh gas will not be contaminated by mixing with the dead products of combustion.

It is much more difficult to secure a full charge of clean mixture with a two-cycle engine than with a four-cycle. In the former, the charging with fresh gases and expulsion of dead gases must take place in half the time allowed in the latter form, and the piston does not pump in a charge or force the burned gases out of the cylinder, as is the case with a four-stroke engine. As the two-cycle motor does not fully expel the burned products it cannot run as fast because of a tendency to choke up at high speeds. In the four-cycle engine a full stroke of the piston is employed in emptying the cylinder, and the natural gas pressure is increased by the reduction of cylinder volume caused by the upwardly moving piston.

In the two-cycle forms the burned gas is discharged through the open exhaust port by its own pressure. If prompt charging and clearing of the cylinder was the only problem to be solved in securing efficient action it would not be difficult to provide large enough ports to attain this end. The port size must be restricted, however, and carefully proportioned because as both intake and exhaust passages are uncovered by the piston at practically the same time a large portion of the incoming gas may be discharged with the burned product, this making for a large fuel consumption and material reduction of efficiency. As the gas is not perfectly clean and pure, some difficulty may be experienced in igniting it. Trouble is also experienced with the cooling, lubrication, and carburetion groups, as most two-cycle motors have peculiarities which make proper oiling and gas supply difficult.

Most automobile designers have adopted the four-cycle power plant, because it has been perfected to a greater degree than the two-cycle, and is easier to keep adjusted and in good running condition. Though the two-cycle motor is undoubtedly the simplest form, it is liable to be erratic in operation and it is sometimes difficult to locate the trouble positively. They consume more fuel than the four-cycle engine of the same power and are not so economical as regards use of lubricating oil. Various types of two-cycle engines which have been designed for automobile use will be described in a following chapter.

Power Plant Installation.—The method of installing the power plant varies on different types of automobiles, though the majority of cars have the engine placed at the extreme front end of the chassis. In some types of cars where single or double cylinder motors of the horizontal type are used the motor is placed under the body. This type of construction is nearly obsolete at this time, and is found only on early forms of vehicles and one or two commercial cars.

The power plant is sometimes combined with the clutch and change speed gearing in such a way as to form a unit construction. This method of joining the parts is widely used at the present time, and is superior to the other common method where the motor and change speed gears are independent units. Each method has advantages. As will be seen by inspecting Fig. 51, A, when the gearset and motor are separate the transmission may be removed from the chassis frame without disturbing the power plant and vice versa. At the other hand, when the unit construction, as shown at B, is employed, it is sometimes difficult to remove one member without having to take the entire unit from the frame.

The unit construction has the advantage of retaining positive alignment of the gearset with the engine indefinitely. This relation between the parts is obtained when they are first assembled and the alignment cannot be changed by any condition of operation after the unit is installed in the frame. This method of mounting also permits the three-point suspension which is very desirable. For instance, the power plant shown at A is supported on four points and the gearset is supported on another series of four points. While the tendency of these members is to brace the frame and prevent dis-

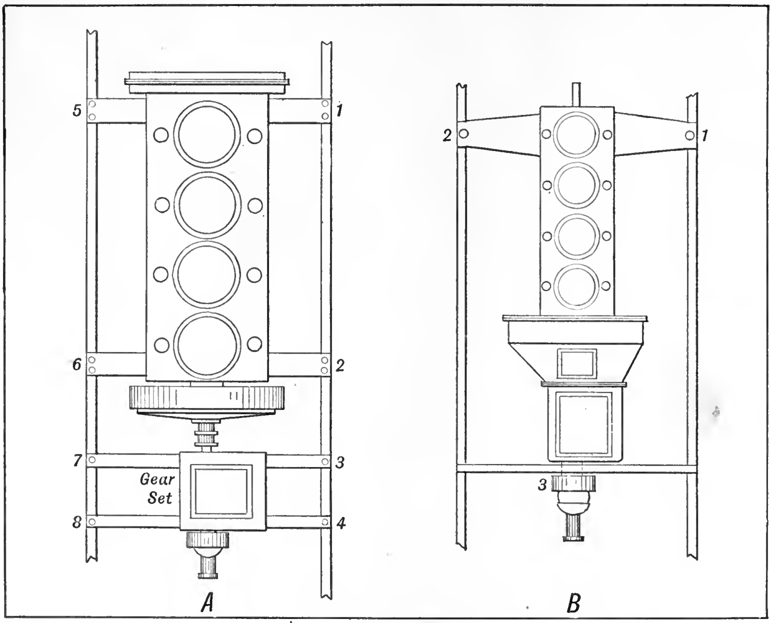


Fig. 51.—Defining Advantages of Unit Power Plant Construction when Supported on Three Points.

alignment, it is possible on extremely rough roads for the frame distortion to vary the relation of the transmission and engine shaft to some extent. Where a three-point suspension is employed, as outlined at B, the frame distortion will not impose stress on the individual members of the power plant because in a rigid unit construction all parts must remain in alignment. The advantages of this design are becoming better appreciated and it is widely used at the present time.

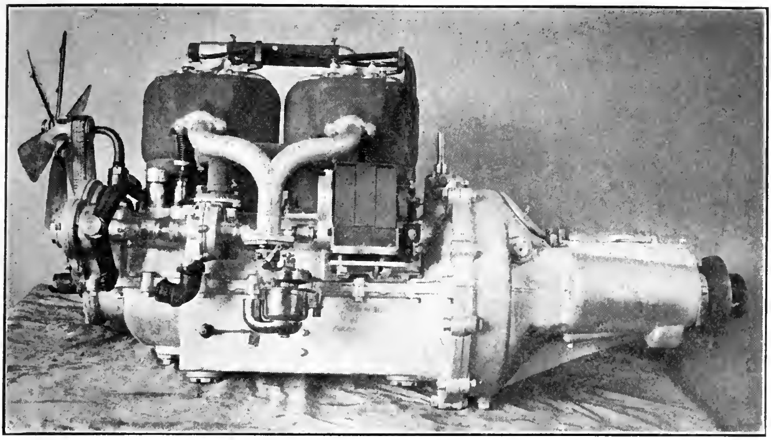


Fig. 52.—Four-Cylinder Power Plant and Transmission Unit Adapted for Three-Point Support.

At Fig. 52, a typical four-cylinder power plant and transmission unit adapted for three-point support is clearly shown, while at Fig. 53 a six-cylinder unit power plant which is designed for attachment to the frame at four points is illustrated. To show the method of power-

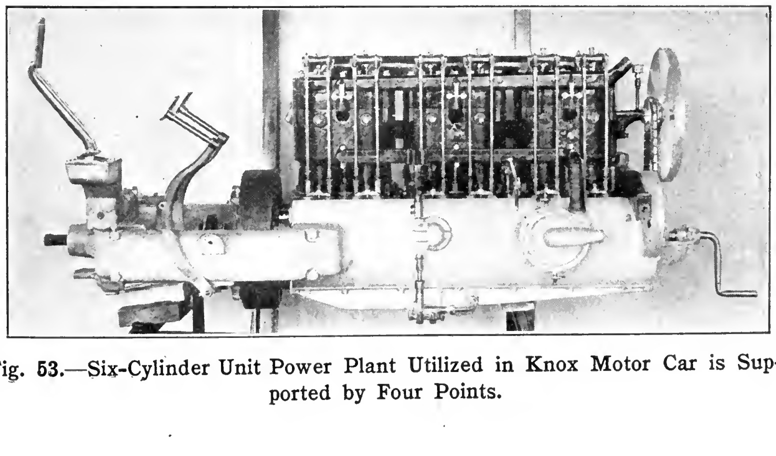


Fig. 53.—Six-Cylinder Unit Power Plant Utilized in Knox Motor Car is Supported by Four Points.

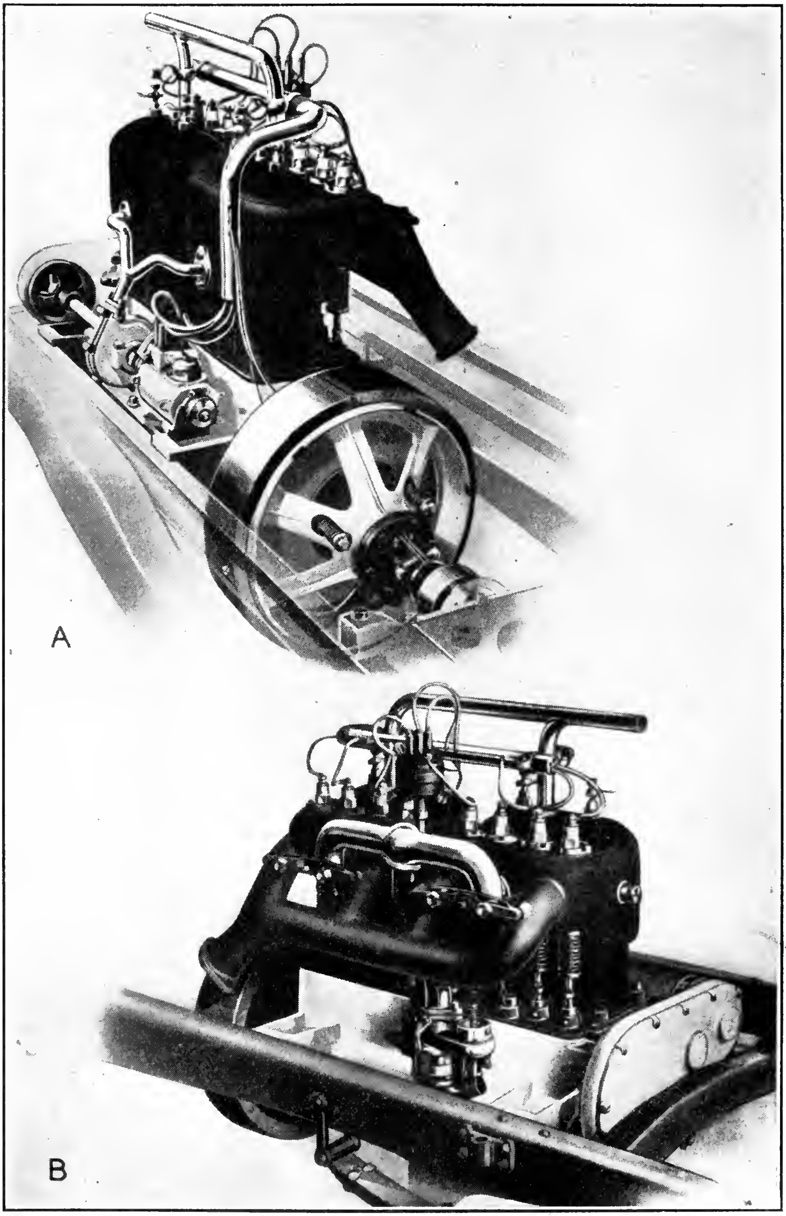


Fig. 54.—Views of Typical Power Plant as Installed in Motor-Car Frame, The Common Method of Installation in Pleasure Cars.

plant installation that is generally employed, the views at Fig. 54 are presented, these representing a typical four-cylinder power plant viewed from the front and rear, showing clearly the method of supporting the engine base by four arms and also outlining the position of the various auxiliary components. In some types of commercial vehicles the motor is installed at the front end under the hood as in pleasure car practice, but in other cases it is placed at practically the same point but under floor boards or driver's seat.

The advantages of the motor under the seat location may be very well summed up by saying that it permits more loading space and less over all or wheel base for a given carrying capacity. The shorter wheel base vehicle is especially valuable in congested city traffic, because it may be more easily controlled when driving in narrow thoroughfares, taking corners, or backing up to a loading platform. The main advantage advanced for the motor in front type of commercial vehicle is accessibility of power plant, which may be easily reached by raising the hood. This feature is not lost when the motor is placed under the seat, however, because all average adjustments may be made by raising the floor boards or by opening a hinged door at the side of the motor compartment. Some makers who install the motor under the seat arrange the components in such a manner that they may be removed as units permitting ready access to the motor and making for its prompt removal in event of overhauling or serious accident. Such a construction is shown at Fig. 55, which depicts a light truck with the seat and dash units removed from the frame. It will be seen that the dash unit includes the radiator, control levers, fuel tank and frame, for the support of the floor boards. The seat unit is separate and is designed to fit over the dash unit when it is in place on the chassis.

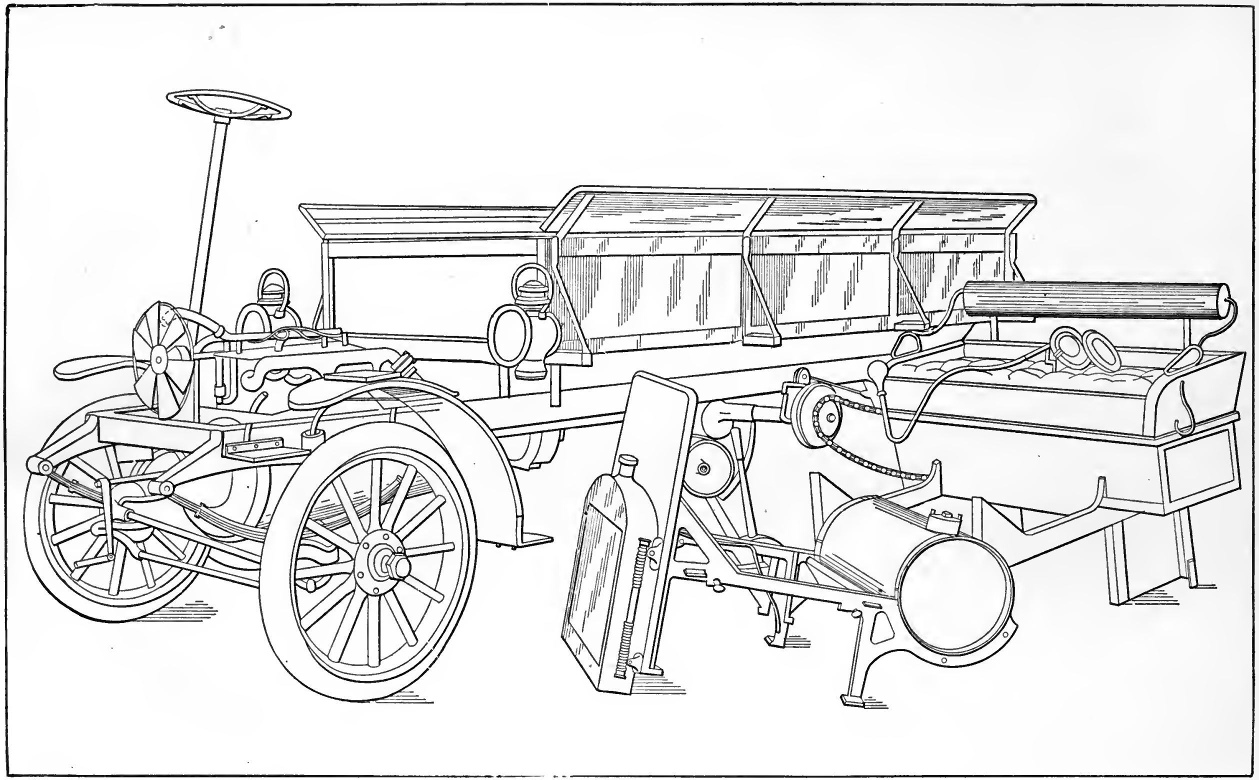


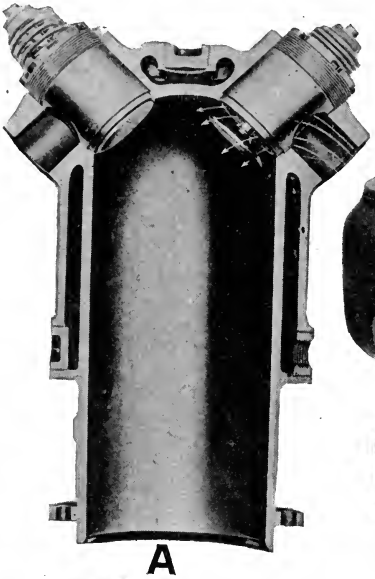
Fig. 55.—Showing Method of Installing Engine in Light Truck. Seat and Dashboard Units Removed to Illustrate Accessibility of Engine if Extensive Repairs are Necessary.

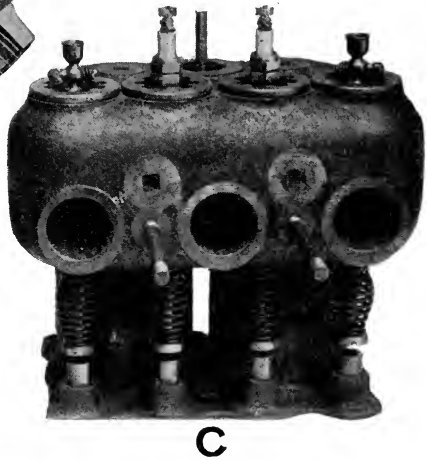
CHAPTER III

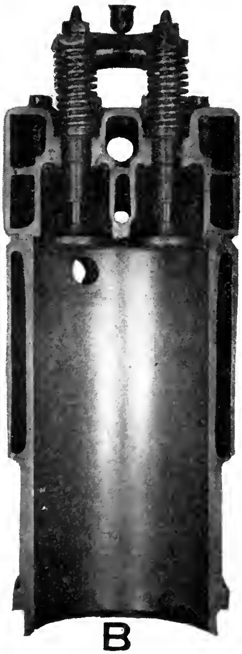
The Principal Parts of Gasoline Engines—Their Design, Construction, and Practical Application in Typical Power Plants—Treating of the Cylinders, Valve System and Valve Timing, Rotary Valve Types, Combination Piston and Sleeve Valve Operation, Ring and Distributor Valve Motor Construction.

The improvements noted in the modern internal combustion motors have been due to many conditions. The continual experimenting by leading mechanical minds could have but one ultimate result. The parts of the engines have been lightened and strengthened, and greater power has been obtained without increasing piston displacement. A careful study has been made of the many conditions which make for efficient motor action, and that the main principles are well recognized by all engineers is well shown by the standardization of design noted in modern power plants. There are many different methods of applying the same principle, and it will be the purpose of this chapter to define the ways in which the construction may be changed and still achieve the same results. The various components may exist in many different forms, and all have their advantages and disadvantages. That all methods are practical is best shown by the large number of successful cars which use radically different designs.

Methods of Cylinder Construction.—One of the most important parts of the gasoline engine and one that has material bearing upon its efficiency is the cylinder unit. Of late there has been a tendency to depart from the previous methods of casting the cylinders individually, or in pairs, and make all cylinders a unit or block casting. Some typical methods of cylinder construction are shown at Fig. 56. The appearance of individual cylinder castings of two different types are shown at A and B. In the former, the cylinder and cylinder head are cast integral and the valves are supported by inserted cages. In the cylinder design shown at B, the head member is a separate casting from that forming the cylinder, and the valves seat directly in this







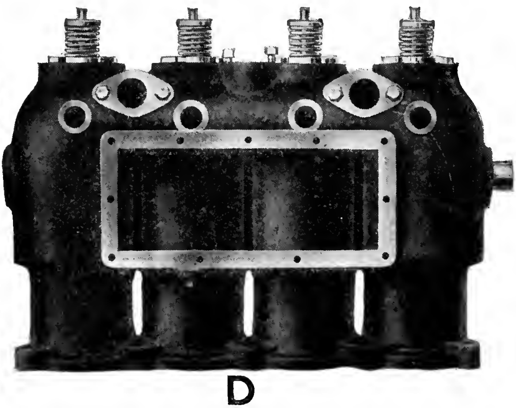


Fig. 56.—Illustrating Differing Methods of Cylinder Construction Commonly Employed. A—Single or One-Cylinder Casting Used on Jackson Cars. B—Individual Cylinder Forming Part of Knox Power Plant. C—Typical Twin Casting Generally Used on Motor Car Engines. D—Four Cylinders Cast in One Block, a Feature of the Chalmers "30" Motor.

member. It is held to the cylinder by means of four bolts. The casting shown at C comprises two cylinders and is the usual form. That at D is a block casting in which the four cylinders are cast together and conforms to up-to-date practice.

Considered from a purely theoretical point of view the individual cylinder casting has much in its favor. It is advanced that more uniform cooling is possible than where the cylinders are cast either in pairs or three or four in one casting. More uniform cooling insures that the expansion or change of form due to heating will be more equal. This is an important condition because the cylinder bore must remain true under all conditions of operation. If the heating effect is not uniform, which condition is liable to obtain if metal is not evenly distributed, the cylinder may become distorted by heat and the bore be out of truth. When separate cylinders are used it is possible to make a uniform water space and have the cooling liquid evenly distributed around the cylinder. In multiple cylinder castings this is not always the rule, as in many instances, especially in four-cylinder block motors where compactness is the main feature, there is no space between the cylinders for the passage of water. Under such circumstances the cooling effect is not even, and the stresses which obtain because of unequal expansion may distort the cylinder to some extent.

The advantage of casting the cylinders in blocks is that a motor may be much shorter than it would be if individual castings were used. It is admitted that when the cylinders are cast together a more compact, rigid, and stronger power plant is obtained than when cast separately. There is a disadvantage, however, in that if one cylinder becomes damaged it will be necessary to replace the entire unit, which means scrapping three good cylinders because one of the four has failed. When the cylinders are cast separately one need only replace that one that has become damaged. The casting of four cylinders in one unit is made possible by improved foundry methods, and when proper provision is made for holding the cores when the metal is poured and the cylinder casts are good, the construction is one of distinct merit. It is sometimes the case that the proportion of sound castings is less when cylinders are cast in block, but if the proper precautions are observed in molding and the proper mixtures of cast iron used, the ratio of defective castings is no more than when cylinders are molded individually. As an example of the courage of modern motor-car engineers in departing from old-established rules, the cylinder casting shown at Fig. 57 may be considered typical. This is a remarkable departure from standard construction, because not only

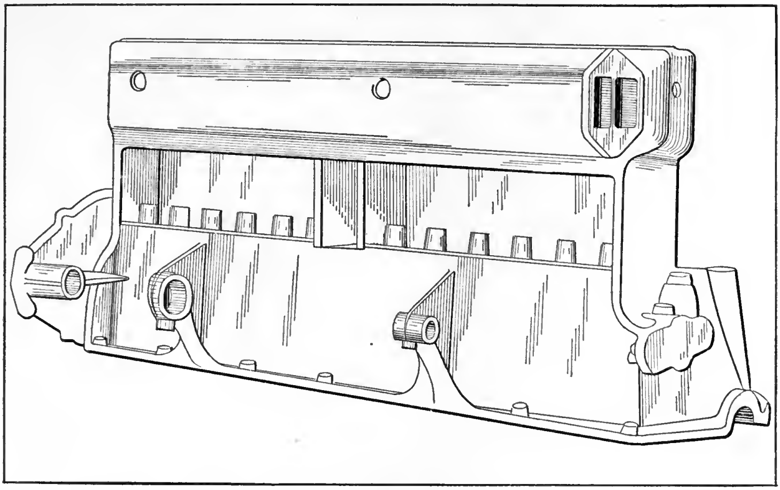


Fig. 57.—Block Casting of Everitt "Six," a Remarkable Innovation in Motor Design Because Six Cylinders, Upper Part of Crank Case and Inlet and Exhaust Manifolds are Included in One Casting.

the six cylinders are cast in a block but the upper part of the engine base and the inlet and exhaust manifold are also included in the one casting.

A method of construction which is attracting some attention at the present time is that shown at Fig. 58. This is a four-cylinder motor in which the four cylinders and the top half of the crank case are cast together, but it employs a separately cast head member which is common to all cylinders. This is held to the cylinder casting by means of a series of bolts, and a copper-asbestos gasket, or packing, is utilized in making a gas- and water-tight joint between the parts The advantage of this construction is that it permits ready access to pistons and valves without dismantling the entire motor as is necessary when the conventional form of cylinder casting is employed. This type of construction is also used on some motors having individually cast cylinders. The member shown at Fig. 56, B, which forms a part of Knox power plant, has a separately cast head, and this construction is also followed in the sleeve valve motors of the Knight type previously described, and in the Argyle motor which is illustrated at Fig. 59.

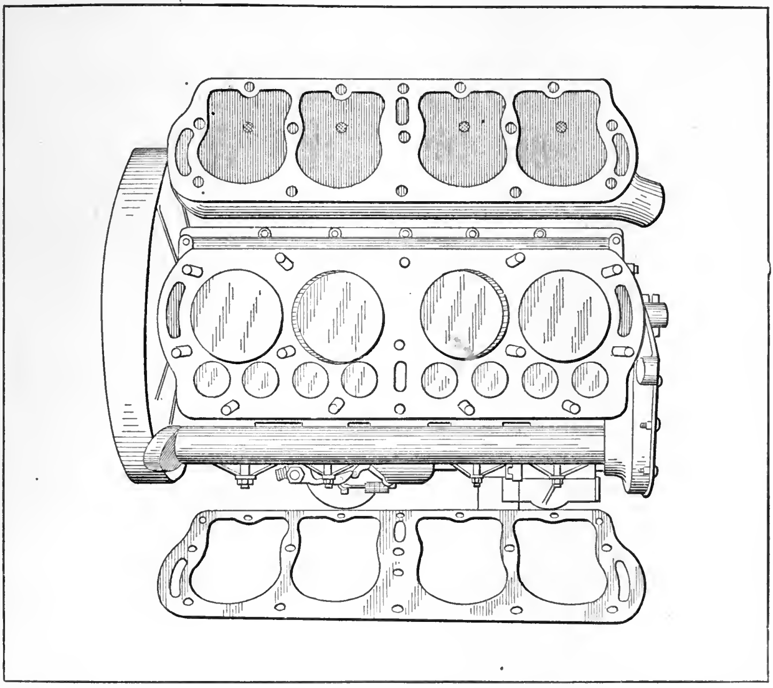


Fig. 58.—Example of Four-Cylinder Block Motor having One Separately Cast Head Member Common to All Cylinders. A Copper-Asbestos Gasket is Utilized in Making a Gas- and Water-Tight Joint Between the Parts. Note Accessibility of Pistons and Valves.

It is common practice to cast the water jackets integral with the cylinders, and this is also the most economical method of applying it because it gives good results in practice. An important detail is that the water spaces must be proportioned so that they are equal around the cylinders whether these members are cast individually, in pairs, threes or fours. When cylinders are cast in block form it is good practice to leave a large opening in the jacket wall which will assist in supporting the core and make for uniform water space. It will be noticed that the casting shown at Fig. 56, D, has a large opening in the side of the cylinder block. These openings are closed after the interior of the casting is thoroughly cleaned of all sand, core wire, etc., by brass, cast iron or aluminum plates. These also have particular value in that they may be removed after the motor has been in use, thus permitting one to clean out the interior of the water jacket and dispose of the rust, sediment, and incrustation which are always present after the engine has been in active service for a time.

Among the advantages claimed for the practice of casting cylinders in blocks may be mentioned compactness, lightness, rigidity, simplicity of water piping, as well as permitting the use of simple forms of inlet and exhaust manifolds. The light weight is not only due to the reduction of the cylinder mass but because the block construction permits one to lighten the entire motor. The fact that all cylinders are cast together decreases vibration, and as the construction is very rigid, disalignment of working parts is practically eliminated. When inlet and exhaust manifolds are cored in the block casting, as is sometimes the case, but one joint is needed on each of these instead of the multiplicity of joints which obtain when the cylinders are individual castings. The water piping is also simplified. In the case of a four-cylinder block motor but two pipes are used; one for the water to enter the cylinder jacket, the other for the cooling liquid to discharge through.

Influence on Crank-Shaft Design.—The method of casting the cylinders has a material influence on the design of the crank shaft as will be shown in proper sequence. When four cylinders are combined in one block it is possible to use a two-bearing crank shaft. Where cylinders are cast in pairs a three-bearing crank shaft is commonly supplied, and when cylinders are cast as individual units it is thought necessary to supply a five-bearing crank shaft, though sometimes shafts having but three journals are used successfully. Obviously the shafts must be stronger and stiffer to withstand the stresses imposed if two supporting bearings are used than if a larger number are em-

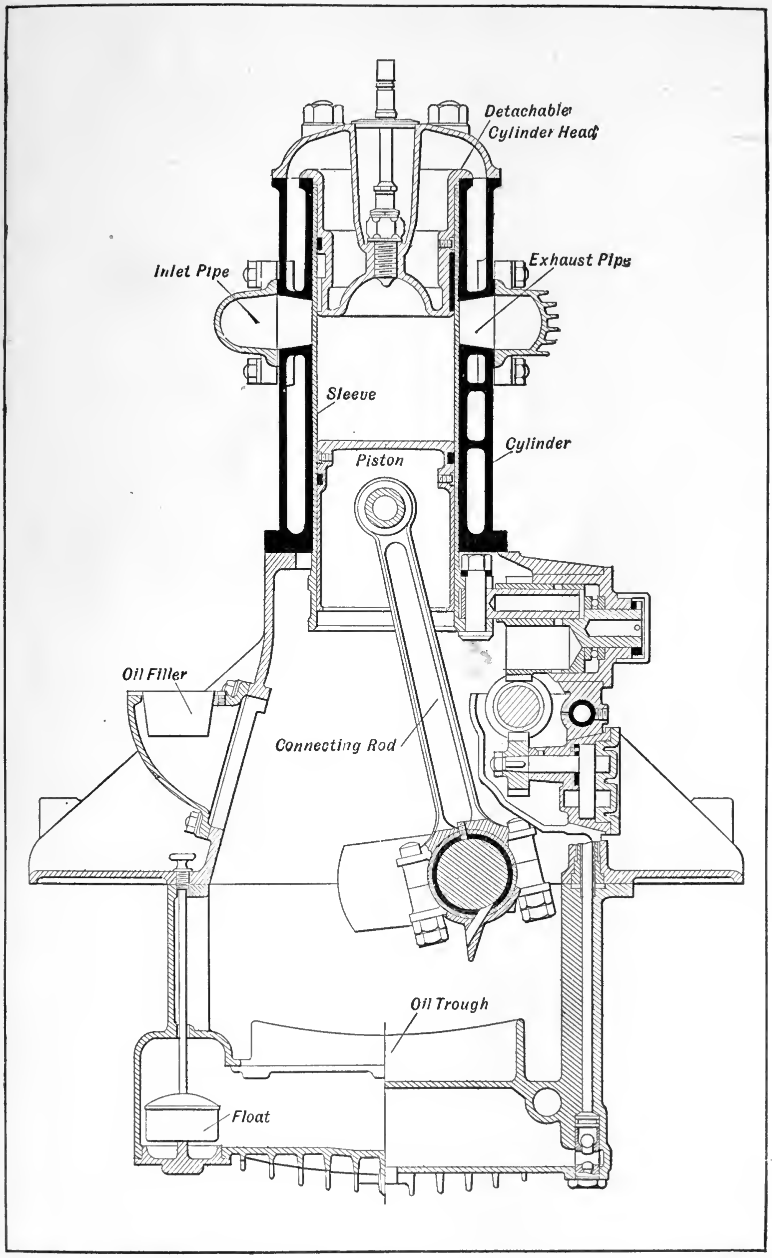


Fig. 59.—Showing Separate Head Construction of Argyl Sleeve Valve Motor, Made Necessary by Use of Sleeve.

ployed. In this connection it may be stated that there is less difficulty in securing alignment with a lesser number of bearings and there is also less friction. At the other hand, the greater the number of points of support a crank shaft has the lighter the webs can be made and still have requisite strength.

Combustion Chamber Design.—Another point of importance in the design of the cylinder and one which has considerable influence upon the power developed, is the shape of the combustion chamber. The endeavor of designers is to obtain maximum power from a cylinder of certain proportions, and the greater energy obtained without increasing piston displacement or fuel consumption the higher the efficiency of the motor. To prevent troubles due to preignition it is necessary that the combustion chamber be made so that there will be no roughness, sharp corners, or edges of metal which may remain incandescent when heated or which will serve to collect carbon deposits by providing point of anchorage. With the object of providing an absolutely clean combustion chamber some makers use a separable head unit such as shown at Fig. 56, B, and Figs. 58 and 59. These permit one to machine the entire interior of the cylinder and combustion chamber. The relation of valve location and combustion chamber design will be considered in proper sequence.

Bore and Stroke Ratio.—A question that has been a vexed one and which has been the subject of considerable controversy is the proper proportion of the bore to the stroke. The early gas engines had a certain well-defined bore to stroke ratio, as it was usual at that time to make the stroke twice as long as the bore was wide, but this cannot be done when high speed is desired. With the development of the present-day motor the stroke or piston travel has been gradually shortened so that the relative proportions of bore and stroke have become nearly equal. Of late there seems to be a tendency among designers to return to the proportions which formerly obtained and the stroke is sometimes one and a half or one and three-quarter times the bore.

Engines designed for high speed should have the stroke not much longer than the diameter of the bore. The disadvantage of short-stroke engines is that they will not pull well at low speeds, though they run with great regularity and smoothness at high velocity. The long-stroke engine is much superior for slow speed work, and it will pull steadily and with increasing power at low speed. It was formerly thought that such engines should never turn more than a moderate number of revolutions in order not to exceed the safe piston speed.

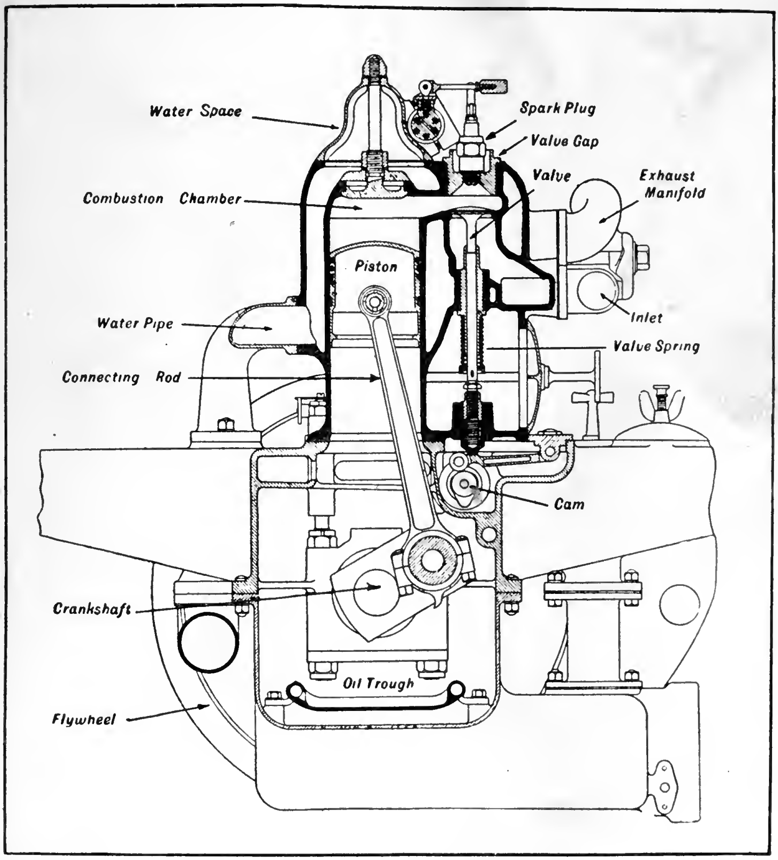


Fig. 60.—Section Through Sheffield Simplex (English) Engine, Presented to Show Excellent Proportions of Water-jacket Spaces and Easy Gas Passages Leading to Valve Chest.

While both short- and long-stroke motors have their advantages it would seem desirable to average between the two. That is why a proportion of four to five or six seems to be more general than that of four to seven or eight, which would be a long-stroke ratio. At Fig. 61 a section through the cylinder of a Sizaire-Naudin motor is shown.

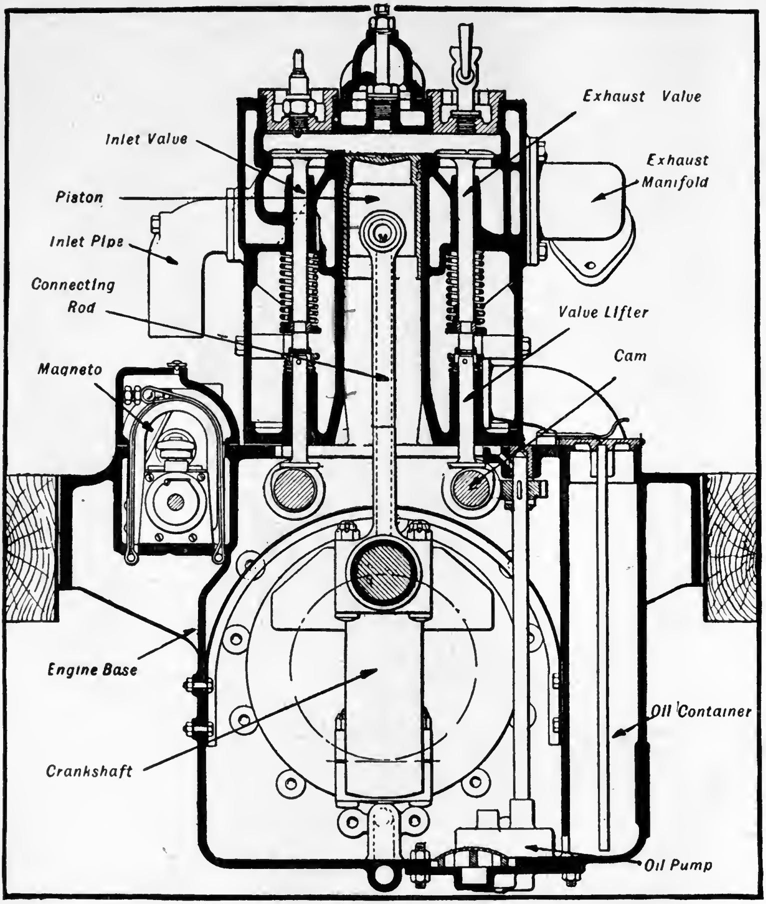


Fig. 61.—Section Through Sizaire-Naudin (French) Motor, Showing a Typical Small-Bore, Long-Stroke Cylinder.

This illustrates a typical small-bore, long-stroke design which has worked very well even at high speeds. That at Fig. 62 is also a long-stroke type.

Meaning of Piston Speed.—The factor which limits the stroke and makes the speed of rotation so dependent upon the travel of the piston is piston speed. Heretofore, it has been considered desirable not to exceed a speed of one thousand feet per minute, which has been determined to make for greatest efficiency, combined with endurance, by many authorities on design and construction of internal combustion motors. During the past few years there have been instances where engines were giving satisfactory service with piston speed of 1,200 to 1,500 feet per minute. Lubrication is the main factor which determines piston speed, and the higher the rate of piston travel the greater care must be taken to insure proper oiling. Let us fully consider what is meant by piston speed.

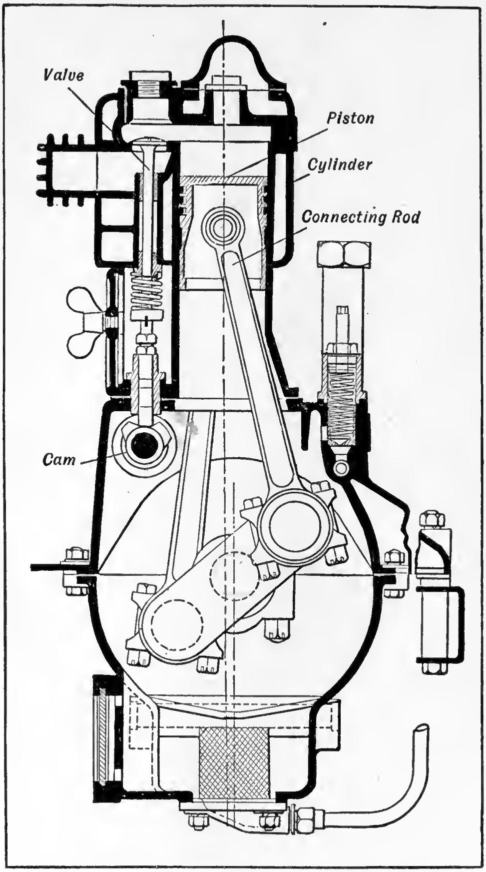


Fig. 62.—End View Humber (English) Motor, Depicting Off-set Cylinder Construction.

Assume that a motor has a piston travel or stroke of six inches, for the sake of illustration. It would take two strokes of the piston to cover one foot, or twelve inches, and as there are two strokes to a revolution it will be seen that this permits of a normal speed of 1,000 revolutions per minute for an engine with a six-inch stroke. If the stroke was only four inches, a normal speed of 1,500 revolutions per minute would be possible without exceeding the prescribed limit. The crank shaft of a small engine, having three-inch stroke, could turn at a speed of 2,000 revolutions per minute without danger of exceeding the safe speed limit. It will be seen that the longer the stroke the slower the speed of the engine, if one desires to keep the piston speed within the bounds as recommended.

Advantages of Off-Set Cylinders.—Another point upon which considerable difference of opinion exists relates to the method of placing the cylinder upon the crank case—i. e., whether its center line should be placed directly over the center of the crank shaft, or to one side of center. The motor shown at Fig. 62 is an off-set type, in that the center line of the cylinder is a little to one side of the center of the crank shaft. Diagrams are presented at Fig. 63 which show the advantages of off-set crank-shaft construction. The view at A is a section through a simple motor with the conventional cylinder placing, the center line of both crank shaft and cylinder coinciding. The view at B shows the cylinder placed to one side of center so that its center line is distinct from that of the crank shaft and at some distance from it. The amount of offset allowed is a point of contention, the usual amount being from fifteen to twenty-five per cent of the stroke. The advantages of the offset are shown at Fig. 63, C. If the crank turns in direction of the arrow there is a certain resistance to motion which is proportional to the amount of energy exerted by the engine and the resistance offered by the load. There are two thrusts acting against the cylinder wall to be considered, that due to explosion or expansion of the gas and that which resists the motion of the piston. These thrusts may be represented by arrows, one which acts directly in a vertical direction on the piston top, the other along a straight line through the center of the connecting rod. Between these two thrusts one can draw a line representing a resultant force which serves to bring the piston in forcible contact with one side of the cylinder wall, this being known as side thrust. As shown at C, the crank shaft is at 90 degrees or about one-half stroke and the connecting rod is at 20 degrees angle. The shorter connecting rod would increase the diagonal resultant and side thrusts while a longer one would reduce the angle and the connecting rod and the side thrust of the piston would be less. With the off-set construction, as shown at D, it will be noticed that with the same connecting rod length as shown at C and with the crank shaft at 90 degrees of the circle that the connecting rod angle is 14 degrees and the side thrust is reduced proportionately.

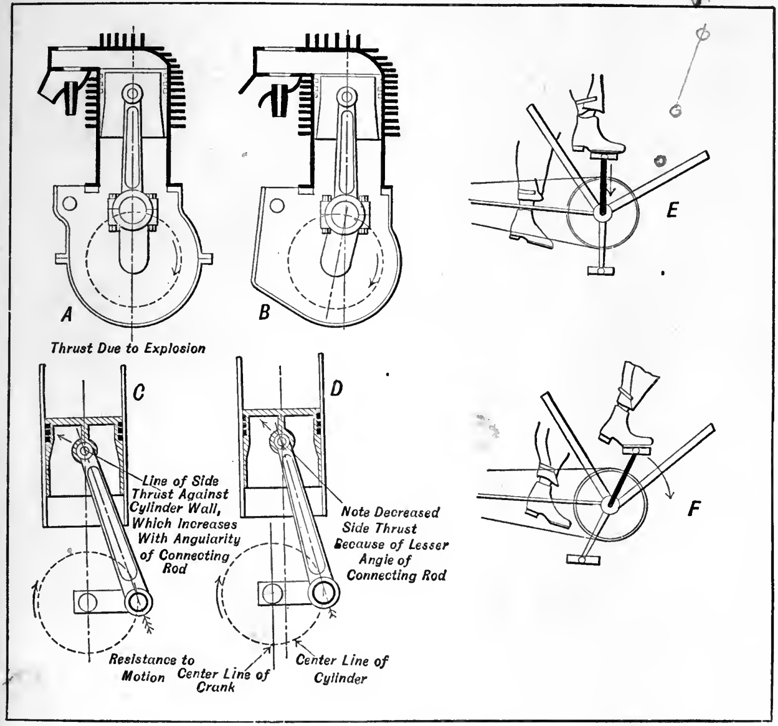


Fig. 63.—Diagrams Demonstrating Advantages of Off-set Crank-Shaft Construction.

Another important advantage is that greater efficiency is obtained from the explosion with an off-set crank shaft, because the crank is already inclined when the piston is at top center and all the energy imparted to the piston by the burning mixture can be exerted directly into producing a useful turning effort. When a cylinder is placed directly on a line with the crank shaft, as shown at A, it will be evident that some of the force produced by the expansion of the gas will be

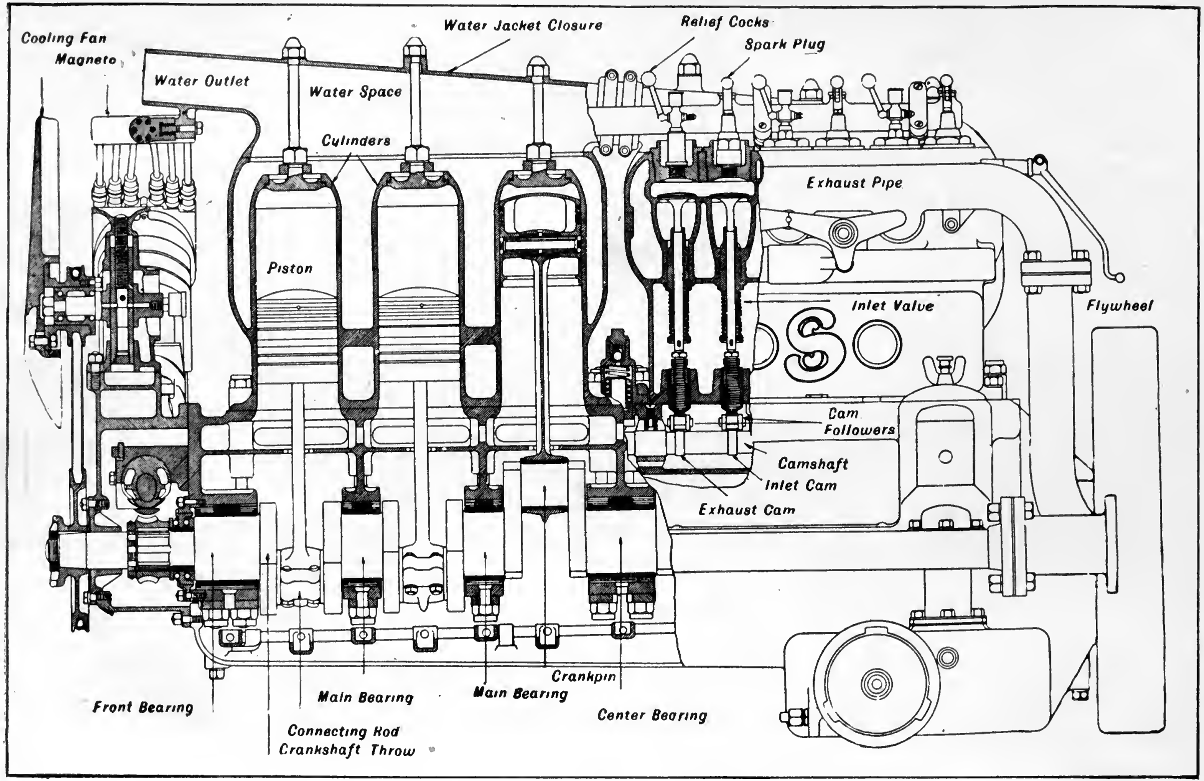


Fig. 64.—Part Sectional View of Sheffield Simplex Six-Cylinder Motor, Showing Use of Block Castings, Seven-Bearing Crank Shaft and Other Constructional Details. Note Exceptionally Good Water-jacketing of Cylinders.

exerted in a direct line and until the crank moves the crank throw and connecting rod are practically a solid member. The pressure which might be employed in obtaining useful turning effort is wasted by causing a direct pressure upon the lower half of the main bearing and the upper half of the crank-pin bushing.

Very good and easily understood illustrations showing advantages of the off-set construction are shown at E and F. This is a bicycle

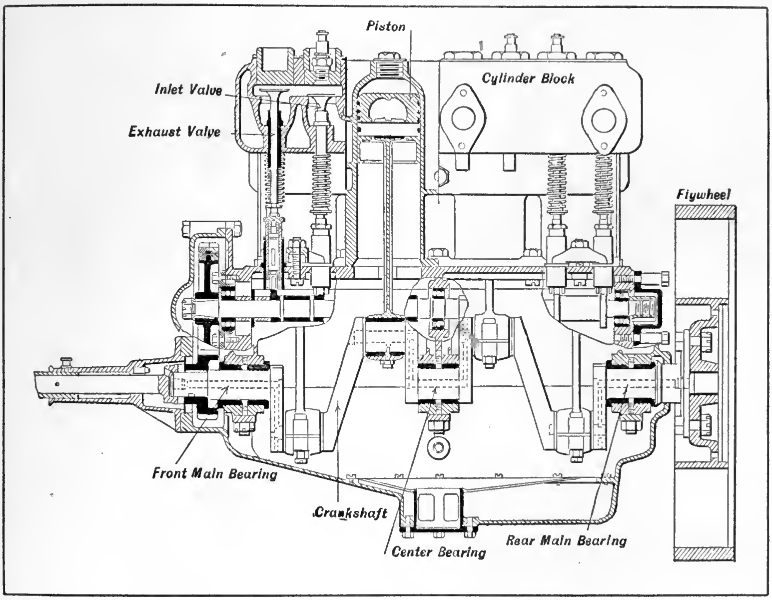


Fig. 65.—Section Through Typical Four-Cylinder Block Motor with Three-Bearing Crank Shaft.

crank hanger. It is advanced that the effort of the rider is not as well applied when the crank is at position E as when it is at position F. Position E corresponds to the position of the parts when the cylinder is placed directly over the crank-shaft center. Position F may be compared to the condition which is present when the off-set cylinder construction is used.

Influence of Cylinder Construction on Engine Design.—To show the manner in which the various methods of casting cylinders previously

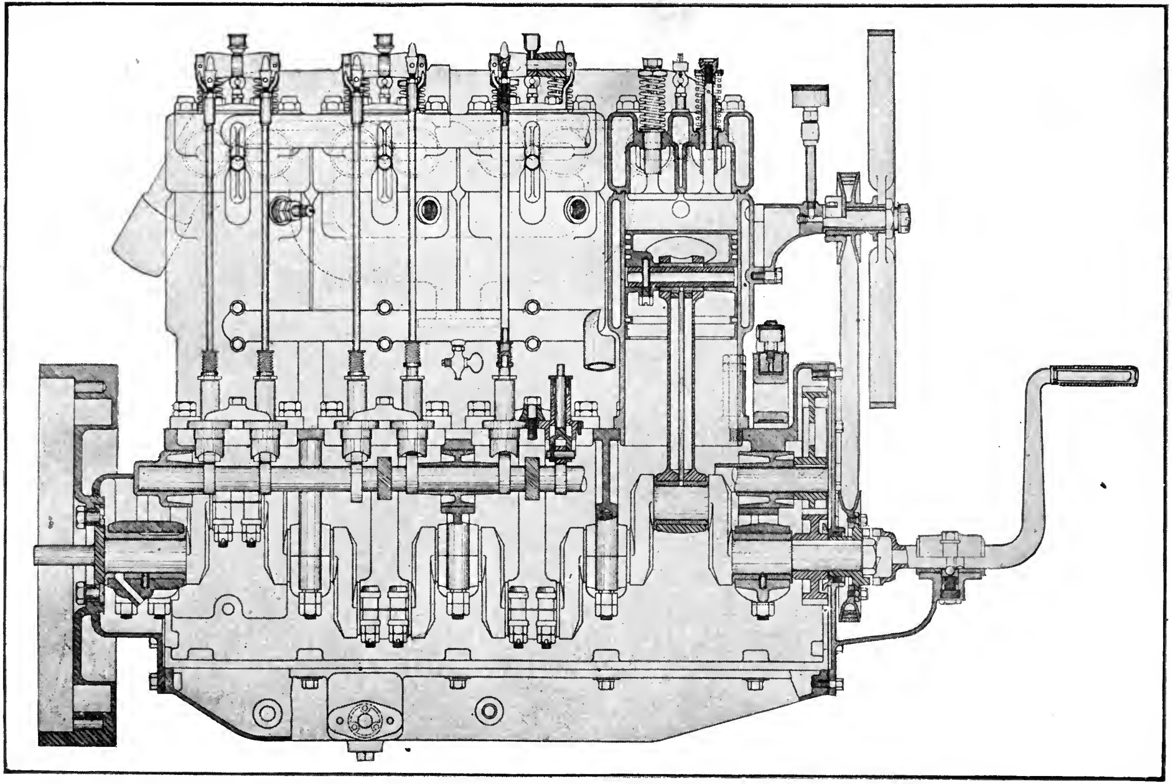


Fig. 66.—Sectional View Knox Model R Motor, Illustrating Application of Individual Cylinder Castings, Separable Head Members and Five-Bearing Crank Shaft. A Simple and Substantial Design that is Enduring and Efficient.

defined may alter engine design some views of typical power plants are presented. That at Fig. 64 is a part sectional view of the Sheffield Simplex, an English six-cylinder motor. In this the cylinders are cast in blocks of three, and the motor is composed of two blocks. A seven-bearing crank shaft is used, there being a journal between each pair of cylinders in addition to the two end members. A feature of this power plant that may be commended is the exceptionally good water jacketing of the cylinders. The water spaces are large and all parts of the cylinder are surrounded by cooling liquid.

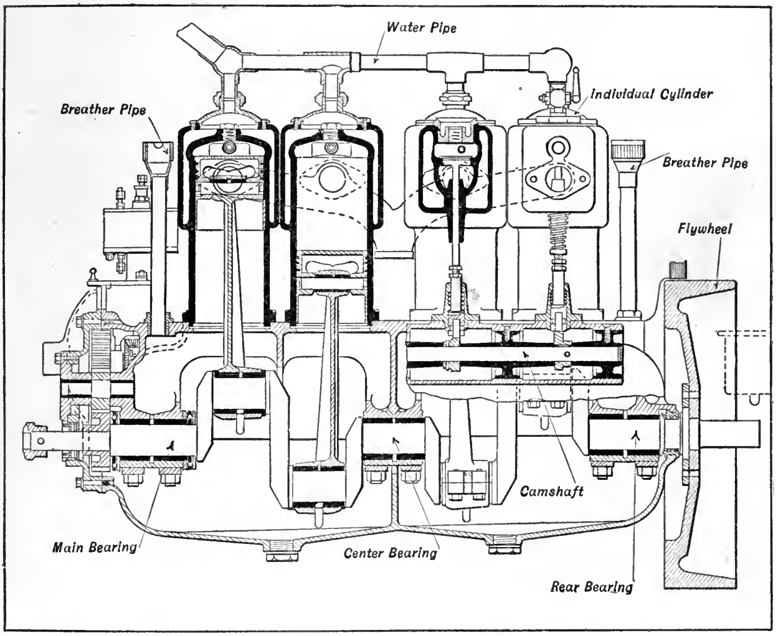


Fig. 67.—Sectional View of Typical Four-Cylinder Motor Using Individual Cylinder Castings with Cylinder Heads Cast Integral. General Design Fair, Excepting that of Connecting Rods.

At Fig. 65 a section through a typical four-cylinder block motor is given. In this power plant a short crank case is used, but the crank shaft is supported on three bearings instead of two journals as is common practice with four-cylinder motors. To show the use of individual castings the motors shown at Figs. 66 and 67 are valuable. It will be evident if these are compared to Fig. 65 that the motor will have a greater overall length than when all cylinders are cast in one block. In the motor shown at Fig 66 a five-bearing crank shaft is employed while that at Fig. 67 uses a three-bearing crank shaft. There are a number of other constructional details dependent upon cylinder design which merit detailed description such as valve placing and operation, crank case design, etc., but these are of sufficient importance to be discussed in a more comprehensive manner and will be considered separately.

Valve Location of Vital Import.—It has often been said that a chain is no stronger than its weakest link and this is as true of the explosive motor as it is of any other piece of mechanism. Many motors which appeared to be excellently designed and which were well constructed did not prove satisfactory, because some minor detail or part had not been properly considered by the designer. A factor having material bearing upon the efficiency of the internal combustion motor is the location of the valves and the shape of the combustion chamber which is largely influenced by their placing. The fundamental consideration of valve design is that the gases be admitted and discharged from the cylinder as quickly as possible in order that the speed of gas flow will not be impeded and produce back pressure. This is imperative in obtaining satisfactory operation in any form of motor. If the inlet passages are constricted the cylinder will not fill with explosive mixture promptly, whereas if the exhaust gases are not fully expelled the parts of the inert products of combustion retained dilute the fresh charge, making it slow burning and causing lost power and overheating. When an engine employs water as a cooling medium this substance will absorb the surplus heat readily, and the effects of overheating are not noticed as quickly as when air-cooled cylinders are employed. Valve sizes have a decided bearing upon the speed of motors and some valve locations permit the use of larger members than do other positions.

While piston velocity is an important factor in determinations of power output it must be considered from the aspect of the wear produced upon the various parts of the motor. It is evident that engines which run very fast, especially of high power, must be under a greater strain than those operating at lower speeds. The valve-operating mechanism is especially susceptible to the influence of rapid movement, and the slower the engine the longer the parts will wear and the more reliable the valve action.

As will be seen by reference to the accompanying illustrations, there are many ways in which valves may be placed in the cylinder. Each method outlined possesses some point of advantage because all of the types illustrated are used by reputable automobile manufacturers. The method outlined at Fig. 68, A, is widely used and because of its shape the cylinder is known as the "T" form. It is approved for several reasons, the most important being that large valves can be employed and a well-balanced and symmetrical cylinder casting obtained. Two independent cam shafts are needed, one operating the inlet valves, the other the exhaust members. The valve-operating mechanism can be very simple in form, consisting of a plunger actuated by the cam which transmits the cam motion to the valve stem, raising the valve as the cam follower rides on the point of the cam. Piping may be placed without crowding, and larger manifolds can be fitted than in some other constructions. This has special value, as it permits the use of an adequate discharge pipe on the exhaust side with its obvious advantages.

At the other hand, if considered from a viewpoint of actual heat efficiency, it is theoretically the worst form of combustion chamber. This disadvantage is probably compensated for by uniformity of expansion of the cylinder because of balanced design. The ignition spark plug may be located directly over the inlet valve in the path of the incoming fresh gases, and both valves may be easily removed and inspected by unscrewing the valve caps without taking off the manifolds.

The valve installation shown at D is somewhat unusual, though it provides for the use of valves of large diameter. Easy charging is insured because of the large inlet valve directly in the top of the cylinder. Conditions may be reversed if necessary, and the gases discharged through this large valve. Both methods are used, though it would seem that the free exhaust provided by allowing the gases to escape directly from the combustion chamber through the overhead valve to the exhaust manifold would make for more power. The

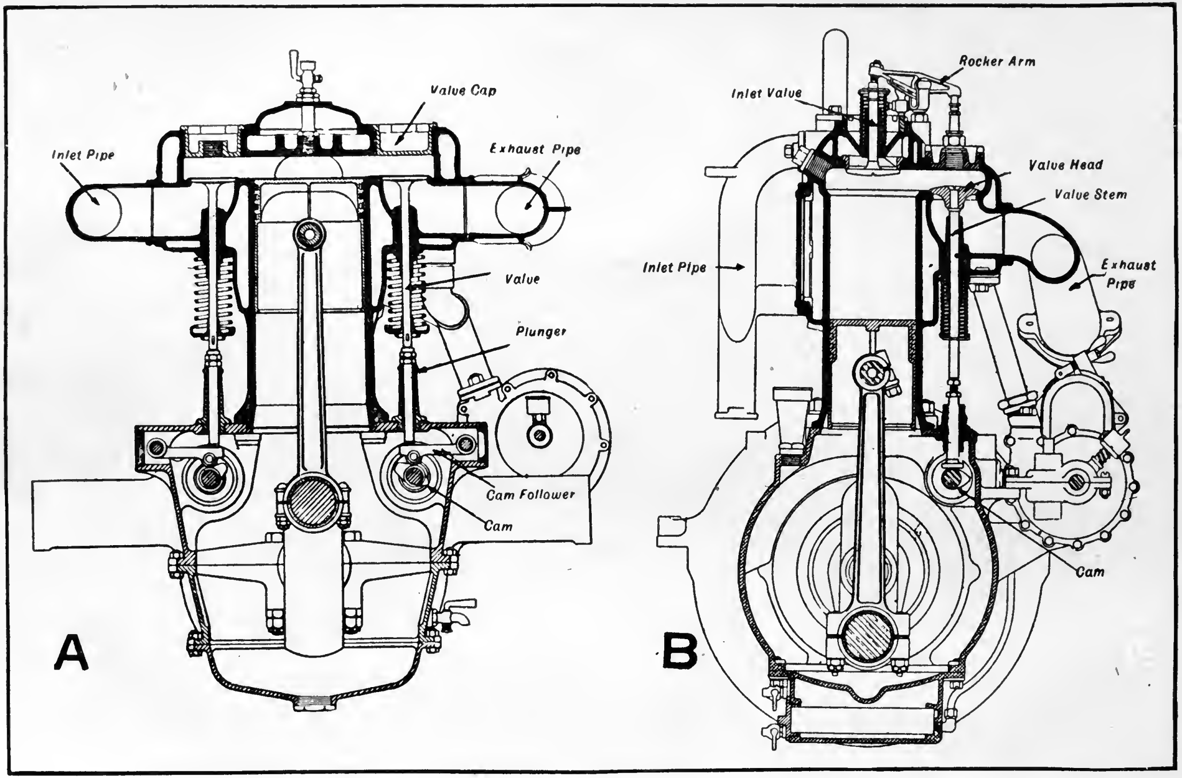


Fig. 68.—Illustrating Typical Methods of Valve Installation in Internal Combustion Motors. A—Valves on Opposite Sides of T Head Cylinder. B—L Head Cylinder Having Intake Valve Placed Directly in the Center of the Cylinder Head.

incoming fresh gas cannot fail to flow into the cylinder easily, because it is drawn into the cylinder by the pumping action of the piston, whereas if the inert gas is not expelled promptly the factor of back

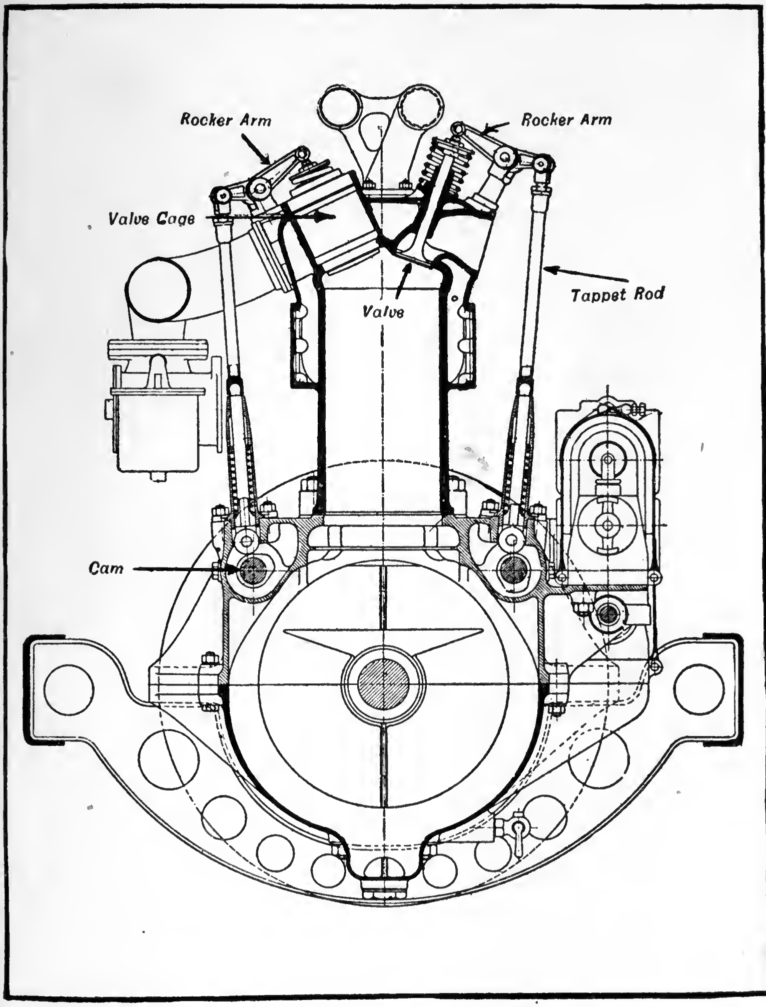


Fig. 69.—Benz Racing Motor, Presented to Show Method of Valve Placing so these Members Open Directly into the Cylinder Head.

pressure is of some importance. The method outlined at Fig. 69 is one that has been widely employed on large racing motors where extreme power as required as well as in engines constructed for regular service. The inclination of the valve cages permits the use of large valves and these open directly into the combustion chamber. There are no pockets to retain heat or dead gas, and free intake and outlet of gas is obtained. This form is quite satisfactory from a theoretical point of view because of the almost ideal combustion chamber form. Some difficulty is experienced, however, in properly water-jacketing the valve chamber which experience has shown to be necessary if the engine is to have high power.

The motor shown at Fig. 62 employs a cylinder of the "L" type. Both valves are placed in a common extension from the combustion chamber, and being located side by side both are actuated from a common cam shaft. The inlet and exhaust pipes are placed on the same side of the engine and a very compact assemblage is obtained. The valves may be easily removed if desired, and the construction is fairly good from the viewpoint of both foundry man and machinist. The chief disadvantage is the limited area of the valves and the loss of heat efficiency due to the pocket. This form of combustion chamber, however, is more efficient than the "T" head construction, though with the latter the use of larger valves probably compensates for the greater heat loss. It has been stated as an advantage of this construction that both manifolds can be placed at the same side of the engine and a compact assembly secured. At the other hand, the disadvantage may be cited that in order to put both pipes on the same side they must be of smaller size than can be used when the valves are oppositely placed. The "L" form cylinder may be made more efficient if but one valve is placed in the pocket while the other is placed in the cylinder head. This construction is well shown at Fig. 70, which is a side sectional view of the same motor depicted in end section at Fig. 68, B. The large valves one can use are well emphasized in this illustration.

The method of valve application shown at Fig. 71 is an ingenious method of overcoming some of the disadvantages inherent with valve-in-the-head motors. In the first place it is possible to water-jacket the valves thoroughly, which is difficult to accomplish when they are mounted in cages. The water circulates directly around the walls of the valve chambers which is superior to a construction where separate cages are used, as there are two thicknesses of metal with the latter,

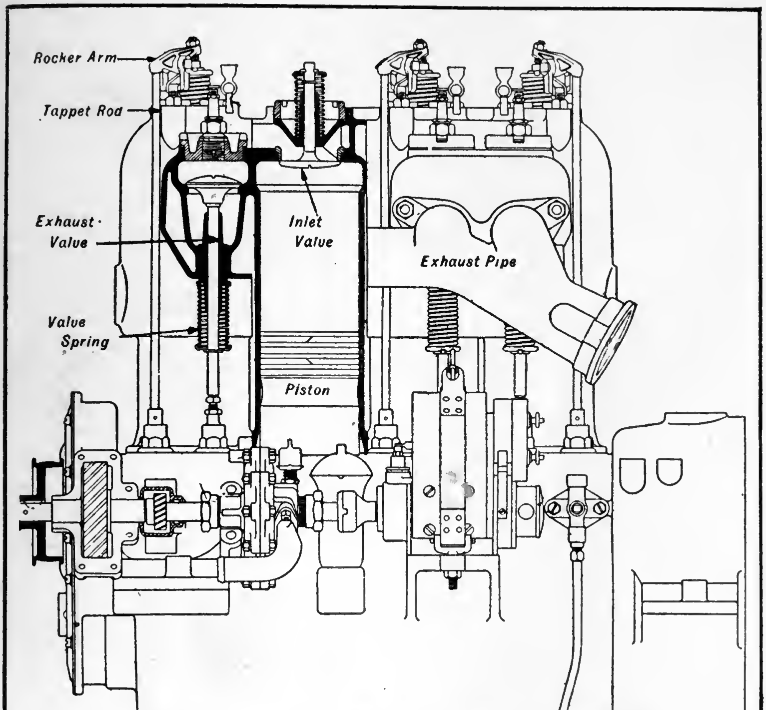


Fig. 70.—Part Sectional View of Bergdoll Motor, Showing Placing of Valves. The Exhaust Member is Fitted in a Side Pocket of the L Cylinder. The Inlet Valve is Placed Directly in the Center of the Combustion Chamber.

that of the valve cage proper and the wall of the cylinder. The cooling medium is in contact only with the outer wall, and as there is always a loss of heat conductivity at a joint it is practically impossible to keep the exhaust valves and their seats at a uniform temperature. The valves may be of larger size without the use of pockets when seating directly in the head. In fact, they could be equal in diameter to almost half the bore of the cylinder, which provides an ideal condition of charge placement and exhaust.

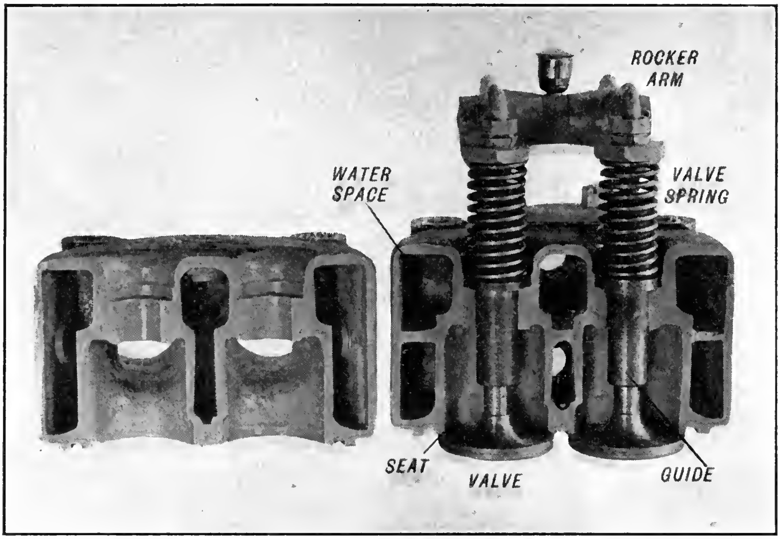


Fig. 71.—Cylinder Head of Knox Engine Cut in Two to Show Method of Valve Placing and Seating Directly in Separately Cast Member. Valves Operated by Rocker Arms. Note Exceptionally Good Water Spaces Around Valve Seats.

When valve grinding is necessary the entire head is easily removed by taking off four nuts and loosening inlet and exhaust manifold connections, which operation would be necessary even if cages were employed. The cylinder is easily cast and machined, and as the head is separately water-jacketed there is no water joint between the head and cylinder which must be made tight with a packing capable of resisting both water and hot gas. The sole function of the copper asbestos washer which fits in the annular groove in the cylinder head is to prevent escape of gas. The ease with which the head and cylinder may be machined and smooth combustion chamber obtained has been previously dealt with.

The form shown at Fig. 72 shows an ingenious application of the valve-in-the-head idea which permits one to obtain large valves. It has been used on some of the Franklin air-cooled cars. The inlet passage is controlled by the sliding sleeve which is hollow and slotted so as to permit the exhaust gases to leave the cylinder and out through the regular type poppet valve which seats in the inlet sleeve. When

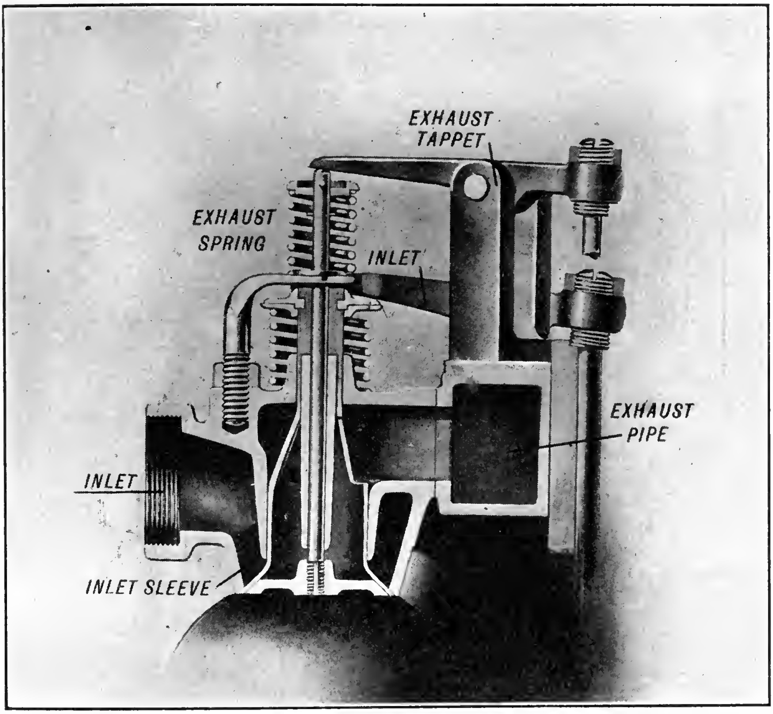


Fig. 72.—Section Through Concentric Valve Used on Some Franklin Models. The Exhaust Valve, which is a Regular Poppet Type, Seats in the Inlet Member, which is a Hollow Shell of Metal. Both Valves Open Directly into the Combustion Chamber.

the inlet sleeve is operated by the tappet rod and rocker arm the exhaust valve is also carried down with it. The exhaust gas passage is closed, however, and the fresh gases are taken in through the large annular passage surrounding the inlet sleeve. When the inlet valve

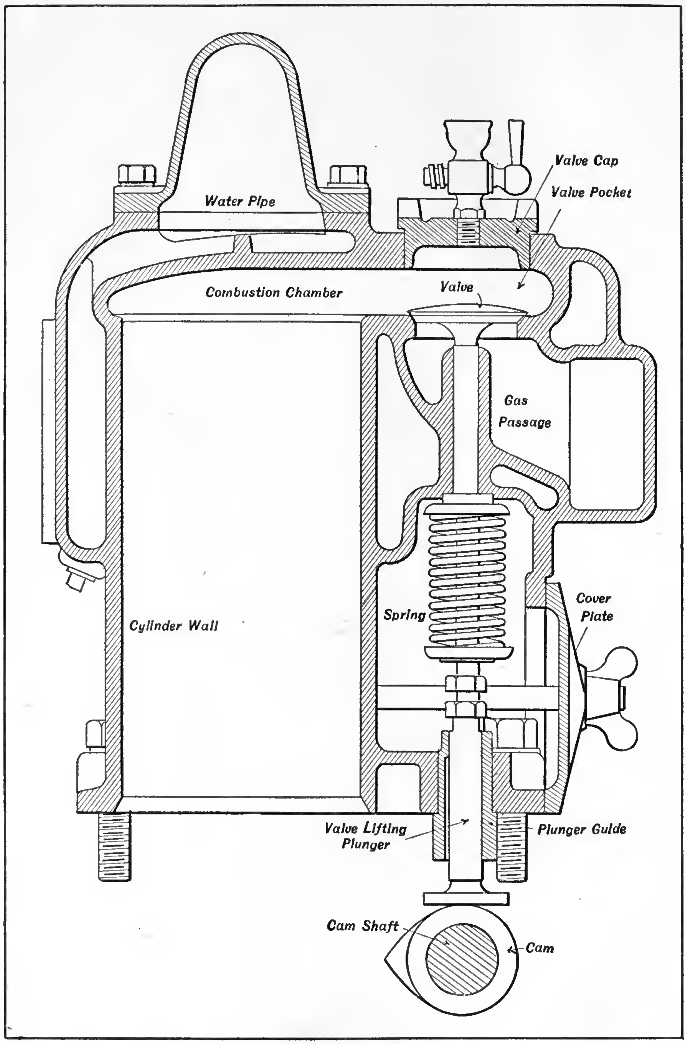


Fig. 73.—Section Through Cylinder of Hudson Car. A Typical Form Having L-shaped Cylinder with Inlet and Exhaust Valves on Same Side of Cylinder and Actuated from Common Cam Shaft. Note Plate Used to Enclose Valve Springs.

leaves its seat in the cylinder the passage of cool gas around the sleeve keeps the temperature of both valves to a low point and the danger of warping is minimized. A dome-shaped combustion chamber may be used which is an ideal form in conserving heat efficiency and as large valves may be installed the flow of both fresh and exhaust gases may be obtained with minimum resistance.

At Fig. 73 a section through a typical "L"-shaped cylinder is depicted. It will be evident that where a pocket construction is employed in addition to its faculty for absorbing heat, the passage of gas would be impeded. For example, the inlet gas rushing in through the open valve would impinge sharply upon the valve cap directly over the valve and then must turn at a sharp angle to enter the combustion chamber and then at another sharp angle to fill the cylinders. The same conditions apply to the exhaust gases, though they are reversed. When the valve-in-the-head type of cylinder is employed the only resistance offered the gas is in the manifold. As far as the passage of the gases in and out of the cylinder is concerned ideal conditions obtain. It is claimed that valve-in-the-head motors are more flexible and responsive than other forms but the construction has the disadvantage in that the valves must be opened through a rather complicated system of push rods and rocker arms instead of the simpler and direct plunger which can be used with either the "T" or "L" head cylinders.

Valve Design and Construction.—Valve dimensions are an important detail to be considered and can be determined by several conditions, among which may be cited method of installation, operating mechanism, material employed, engine speed desired, manner of cylinder cooling, and degree of lift desired. A review of various methods of valve location has shown that when the valves are placed directly in the head, we can obtain the ideal cylinder form though larger valves may be used if housed in a separate pocket, as afforded by the "T" head construction. The method of operation has much to do with the size of the valves. For example, if an automatic inlet valve is employed it is good practice to limit the lift and obtain the required area of port opening by augmenting the diameter. Because of this a valve of the automatic type is usually made twenty per cent larger than one mechanically operated. When both are actuated by cam mechanism, as is now common practice, they are usually made the same size and are interchangeable, which greatly simplifies manufacture. The relation of valve diameter to cylinder bore is one that has been discussed for some time by engineers. The writer's experience would indicate that they should be at least half the bore, if possible. The larger the area of the valve the less lift required, and this is an important factor where high rotative speeds are desired. A valve with a small lift will reach its maximum opening sooner and close quicker than one with a high lift and small diameter. This will produce less wear on the parts and tend to more silent operation.

At the other hand, a large diameter valve is more apt to warp than a narrower one, and greater care is needed in securing positive cooling

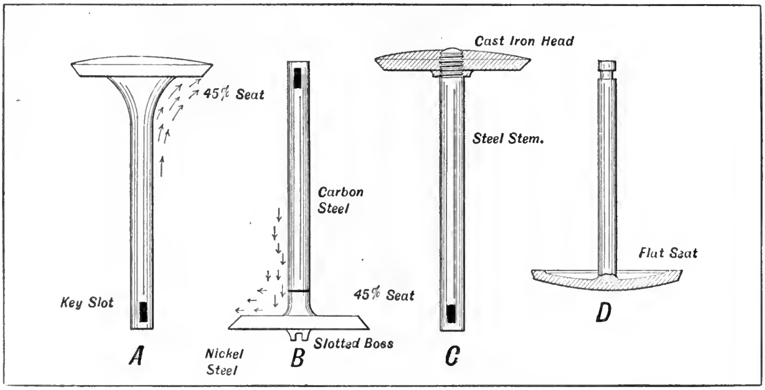


Fig. 74.—Type of Valves in Common Use. A—One-Piece Steel Valve of Good Design which Permits Easy Gas Flow. B—Steel Valve Made by Electrically Welding a Nickel Steel Head to a Carbon Steel Stem. C—A Construction Often Employed for Exhaust Valves, a Two-Piece Built-Up Member. D—Valve with Flat Seat, Often Used to Admit Mixture to Cylinder.

when large diameter members are used. While the mushroom type or poppet valve has become standard and is the most widely used form at the present time, there is some difference of opinion among designers as to the materials employed and the angle of the seat. Most valves have a bevel seat, though some have a flat seating, as shown at Fig. 74, D. The flat seat valve has the distinctive advantage of providing a clear opening with lesser lift, this conducing to free gas flow. It also has value because it is silent in operation, but the disadvantage is present that best material and workmanship must be used in their construction to obtain satisfactory results. As it can be made very light it is particularly well adapted for use as an automatic inlet valve. Among other disadvantages cited is the claim that it is more susceptible to derangement owing to the particles of foreign matter getting under the seat. With a bevel seat valve it is argued that the foreign matter would be more easily dislodged by the gas flow, and that the valve would close tighter because it is drawn positively against the bevel seat.

Several methods of valve construction are the vogue, the most popular form being the one-piece type; though those which are composed of a head of one material and stem of another are often used. If the built-up construction is favored the head is usually of high nickel steel, Monel metal, or cast iron, which metals possess good heat resisting qualities. Heads made of these materials are not likely to warp, scale, or pit, as is sometimes the case when ordinary grades of machinery steel are used. The cast-iron head construction is not popular because it is often difficult to keep the head tight on the stem. There is a slight difference in expansion ratio between the head and the stem, and as the stem is either screwed or riveted to the cast-iron head the constant hammering of the valve against its seat may loosen the joint. As soon as the head is loose on the stem the action of the valve becomes erratic.

The valve shown at Fig. 74, A, is made from a forging of thirty-five per-cent nickel steel in the large sizes, and is often machined from the bar by automatic machinery in making the smaller sizes. Among the factors considered in design are to make the stems of ample size so that they will not be likely to bend, and to leave enough metal between the stem and the head so that the gases may be directed toward the periphery of the head. This has a tendency to make a slightly heavier valve than that shown at Fig. 74, B. It is also considered good practice to use a domed or arched head instead of one that is perfectly flat, and it is advisable to leave the head smooth and without a slotted boss which is often left on so that a screw-driver blade can be used to turn the valve when grinding it. When the arched head construction is used two small holes may be drilled into it. These have the advantage of leaving no sharp edges exposed to retain heat and cause too early explosions of gas. If desired, a slot may be cut directly in the head and the valve turned with a screw-driver.

The form of valve shown at B is a common one, and its only advantage is that the design permits of light construction. The slotted boss is not desirable for the reason previously outlined, the valve head is not as strong as that shown at A and it will warp sooner. The point of weakness where the stem joins the head may cause trouble. As the gases strike the under surface and are sharply deflected at a sharp angle instead of having an easy flow the passage is somewhat impeded. The form of construction is a nickel steel head electrically welded to a machinery steel stem. The former material is a better heat-resisting substance while the softer steel makes a better bearing. The joint is indistinguishable because the metals are fused together, and that point is as strong as any other part of the stem. The valve shown at C is composed of a cast-iron head member screwed on to a steel stem. The construction at D is a good example of flat seat inlet valve.

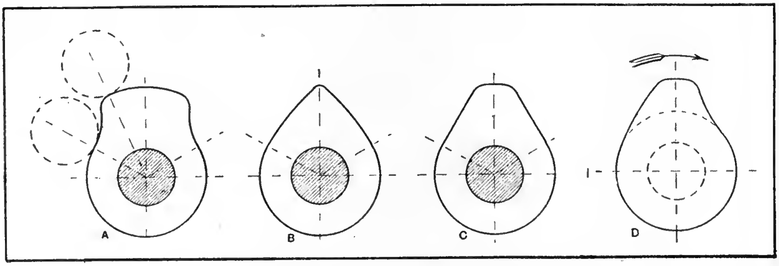


Fig. 75.—Forms of Valve-Lifting Cams Generally Employed. A—Cam Profile for Long Dwell and Quick Lift. B—Typical Inlet Cam Used with Mushroom Type Follower. C—Average Form of Cam. D—Designed to Give Quick Lift and Gradual Closing.

Valve Operation.—The methods of valve operation commonly used vary according to the type of cylinder construction employed. In all cases the valves are lifted from their seats by cam actuated mechanism. Various forms of valve-lifting cams are shown at Fig. 75. As will be seen, a cam consists of a circle to which a raised, approximately triangular member has been added at one point. When the cam follower rides on the circle, as shown at Fig. 76, there is no difference in height between the cam center and its periphery and there is no movement of the plunger. As soon as the raised portion of the cam strikes the plunger it will lift it, and this reciprocating movement is transmitted to the valve stem by suitable mechanical connections.

The cam forms outlined at Fig. 75 are those commonly used. That at A is used on engines where it is desired to obtain a quick lift and to keep the valve fully opened as long as possible. It is a noisy form, however, and is not very widely employed. That at B is utilized more often as an inlet cam while the profile shown at C is generally depended on to operate exhaust valves. The cam shown at D is a composite form which has some of the features of the other three types. It will give the quick opening of form A, the gradual closing of form B, and the time of maximum valve opening provided by cam profile C.

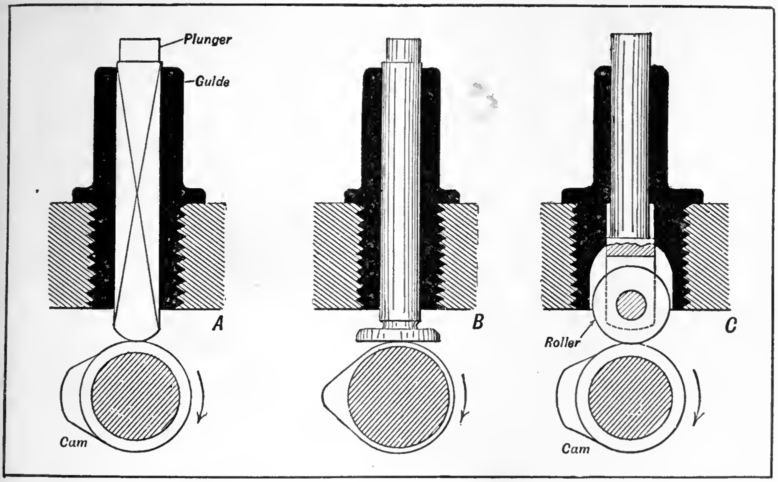


Fig. 76.—Showing Principal Types of Cam Followers which Have Received General Application.

The various types of valve plungers used are shown at Fig. 76. That shown at A is the simplest form, consisting of a simple cylindrical member having a rounded end which follows the cam profile. These are sometimes made of square stock or kept from rotating by means of a key or pin. A line contact is possible when the plunger is kept from turning whereas but a single point bearing is obtained when the plunger is cylindrical and free to revolve. The plunger shown at A will follow only cam profiles which have gradual lifts. The plunger shown at B is left free to revolve in the guide bushing and is provided with a flat mushroom head which serves as a cam follower. The type shown at C carries a roller at its lower end and may follow very irregular cam profiles if abrupt lifts are desired. While forms A and B are the simplest, that outlined at C in its various forms is more widely used.

The illustrations at Fig. 77 show some of the different possible methods of valve operation. At A the application of a rocker arm and tappet rod to operate an overhead valve is clearly depicted. The rocker arm is interposed in order that the upward movement of the tappet rod will produce a down movement of the valve stem. The method of valve operation shown at B is possible when it is desired to operate both valves of a "T" head cylinder from a common cam shaft. One of the valves is lifted directly by the usual cam actuated plunger, while the other member is raised from its seat by a plunger operated from the cam through a centrally pivoted simple lever. At C the simplest method of valve operation is shown. The cylinder casting is a twin "L" form, and the valves are placed side by side in the pocket at one side of center. They are operated directly by means of simple mushroom head plungers guided in bushings secured in bosses formed integrally with the cylinder base. These plungers bear against the lower end of the valve stems.

All the methods in which levers are used to operate valves are more or less noisy because clearance must be left between the valve stem and the top of the plunger. The space must be taken up before the valve will leave its seat, and when the engine is operated at high speeds the forcible contact between the plunger and valve stem produces a pronounced hammering sound. At D a method of indirect valve operation is shown. The main purpose is to obtain silent working and to permit the valves being arranged in any convenient position. Instead of using direct cam action against the end of the valves, the valves are lifted from their seats by a liquid under pressure. The cams are placed across the front of the engine, though they could be placed at

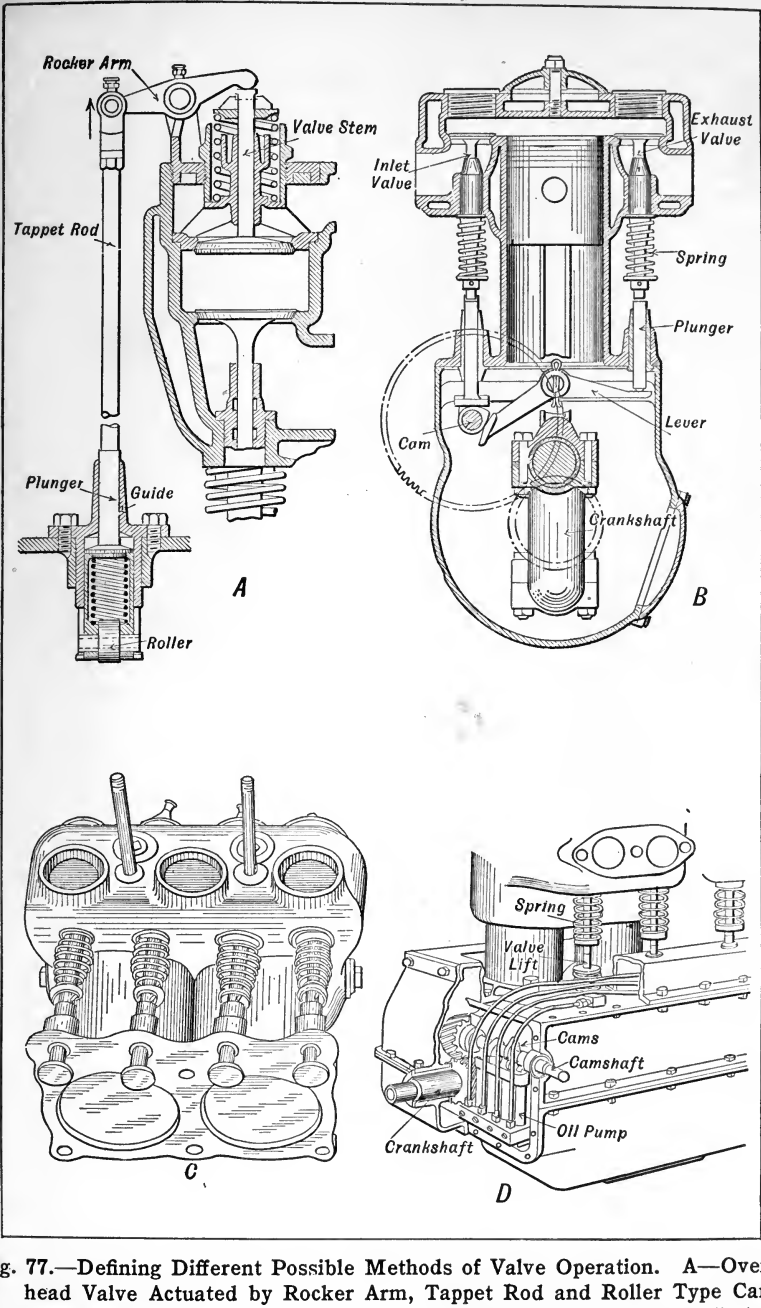


Fig. 77.—Defining Different Possible Methods of Valve Operation. A—Overhead Valve Actuated by Rocker Arm, Tappet Rod and Roller Type Cam Follower. B—Both Valves Operated from One Cam, "T" Head Cylinder. C—Valves of "L" Type Twin Cylinder Casting Operated by Mushroom Type Cam Followers. D—Suggested Method of Indirect Valve Operation.

any other point so long as they could be conveniently driven from the crank shaft.

There are eight cams, one for each valve, and under each cam an oil force pump is placed. This is connected by a tube to a plunger under the valve stem. Each pipe is filled with oil, and when the cam operates its particular pump the incompressible liquid in the pipe is forced against the plunger under the valve and the valve is lifted. Instead of the cam pushing the tappet and the plunger pushing the valve, as in other constructions described, the cam works a pump and this in turn a tappet. The return of the valve stem is effected by the valve springs in the usual way. Each oil pump is also provided with a return spring which keeps the roller on top of the pump plunger bearing against the cam. The whole of the cam action is in an oil bath and any leakage of liquid from the pipes is automatically compensated for through a simple form of ball valve. Each pipe is always full of oil as long as there is any in the bath.

As it is not possible to compress the liquid, it may be stated broadly that the driving effect is the same as though the oil pipes were filled with steel balls. The simile is not a correct one, because the fluid pressure provides a softness and silence of action which could not be very well obtained by direct operation. It is also expected that clearance between the valve stem and operating plungers will not be necessary because the slight leakage of working fluid will compensate for any expansion of the valves and the resulting lengthening of the stems automatically. It is not expected that this method of valve operation will be used to any extent because the mechanism is more complicated than when simple direct lift plungers are employed. With modern forms of plungers which are provided with suitable adjusting features which make it possible to maintain a minimum clearance between valve stem and lifting member, the valve action is silent enough so that it would not pay to introduce a complicated hydraulic system as that described. This has been presented mainly to show that valves may be operated by other means than direct cam and plunger action.

We have seen that the method of valve placing has material bearing on the system of valve-actuating mechanism employed. At Fig. 78 the various methods of valve installation are presented in diagrammatic form and will assist the reader in obtaining a clear idea of the valve placings most commonly used. With the "T" head cylinder as shown at A separate cam shafts are usually employed and the valves are raised by direct lift plungers. The "L" head cylinder as de-

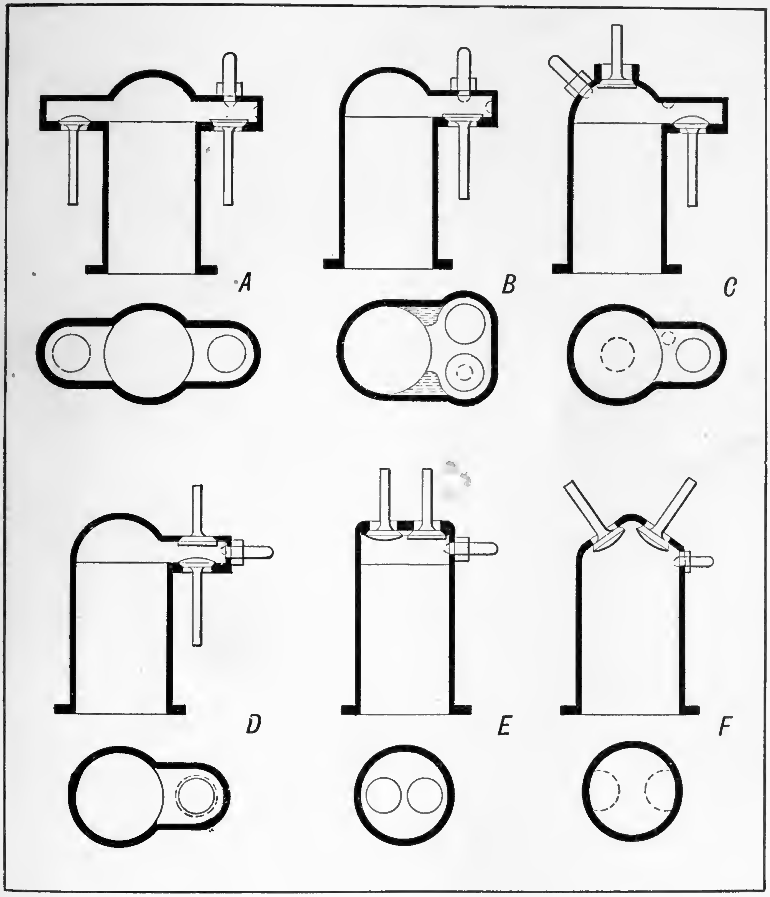


Fig. 78.—Diagram Showing Forms of Cylinder Demanded by Different Valve Placings. A—T Head Type, Valves on Opposite Sides. B—L Head Cylinder, Valves Side by Side. C—L Head Cylinder, One Valve in Head, Other in Pocket. D—Inlet Valve Over Exhaust Member, Both in Side Pocket. E—Valve-in-the-Head Type with Vertical Valves. F—Inclined Valves Placed to Open Directly into Combustion Chamber.

picted at B calls for but one cam shaft, and as is true of the previous case the valves may be lifted directly from their seats by a simple cam follower. At C the valve location demands the use of an overhead rocker arm which may be actuated from the same cam shaft which is employed to raise the exhaust valve from its seat. At D a method of valve placing is shown which is very popular on small motors used for motorcycle propulsion. The inlet valve is placed directly over the exhaust member and may be automatically operated or may be depressed by the conventional form of rocker arm. When overhead valves are used, as shown at E, two rocker arm assemblies are needed and both valves are operated from a common cam shaft. With the form shown at F having inclined valves two sets of rocker arms may be

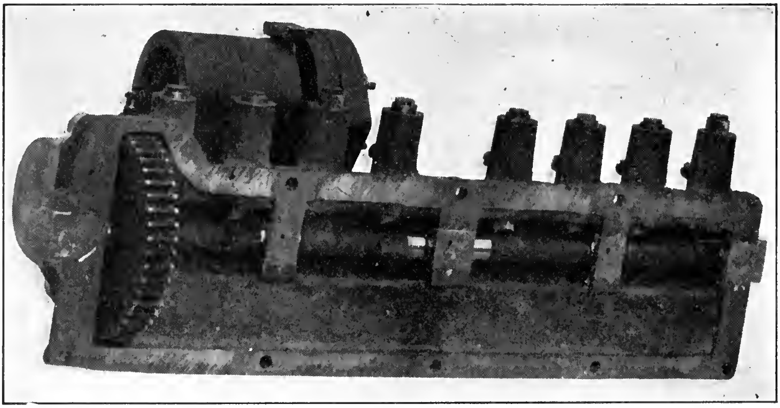


Fig. 79.—Cam Shaft and Valve Operating Plunger Case of Hupp Motor, a Separate Member. Note Simple Type of Cam Follower.

used actuated by two cam shafts, one on each side of the motor. Sometimes a single rocker arm is fulcrumed at the center, having one extremity bearing on each valve stem. The lever is rocked by a special form of cam provided with a depression as well as a raised portion. When the tappet rod is raised it may depress one of the valves, whereas when the cam follower drops in the depression of the cam the other end of the rocker arm will fall and open the other valve.

A cam case assembly, such as used on the Hupp motor, is shown at

Fig. 79. This is bolted to the side of the engine base and the large gear attached to the cam shaft is driven from a suitable gear on the crank shaft at half the engine speed. The cam followers are the simple form shown at Fig. 76, A. They are provided with a fiber inset at their top end which comes into contact with the valve stem. The use of this material tends to reduce noise which would be present if two metals came in contact.

Methods of Driving Cam Shaft.—Two systems of cam shaft operation are used. The most common of these is by means of gearing of some form. If the cam shaft is at right angles to the crank shaft it may be driven by worm, spiral, or bevel gearing. If the cam shaft is parallel to the crank shaft, simple spur gear or chain connection may be used to turn it. At Fig. 80 a conventional system of cam gears is shown. The front of the gear case has been removed, this exposing the gear train which drives the cam shaft and accessory mechanism. A small gear having thirty-two teeth is placed on the crank shaft. This engages a larger member having sixty-four teeth turning it at one-half its speed. This large gear is securely fastened to a flange on the cam shaft by three bolts. At the right an idler gear meshes with the crank-shaft gear and serves to transmit motion from that member to the small gear at the extreme right which is utilized to drive the circulating pump shaft and the magneto employed for ignition.

While gearing is more commonly used, considerable attention has been directed of late to silent chains for cam shaft operation. The ordinary forms of block or roller chain have not proven successful in this application, but the silent chain, which is in reality a link belt operating over toothed pulleys, has demonstrated its worth. The tendency to its use is more noted on foreign motors than those of American design. It first came to public notice when employed on the Daimler-Knight engine for driving the small auxiliary crank shafts which reciprocated the sleeve valves.

At Fig. 81 two efficient cam shaft drives are illustrated. That at A is furnished on the Wolseley 1912 motors. It will be observed that the small gear on the crank shaft is coupled to a larger gear on the cam shaft by one chain, while a separate gear wheel and chain drives the magneto from the cam shaft. The sprockets are so proportioned that the cam shaft revolves at half the engine speed, while the magneto is speeded up so it will have the same speed as the crank shaft.

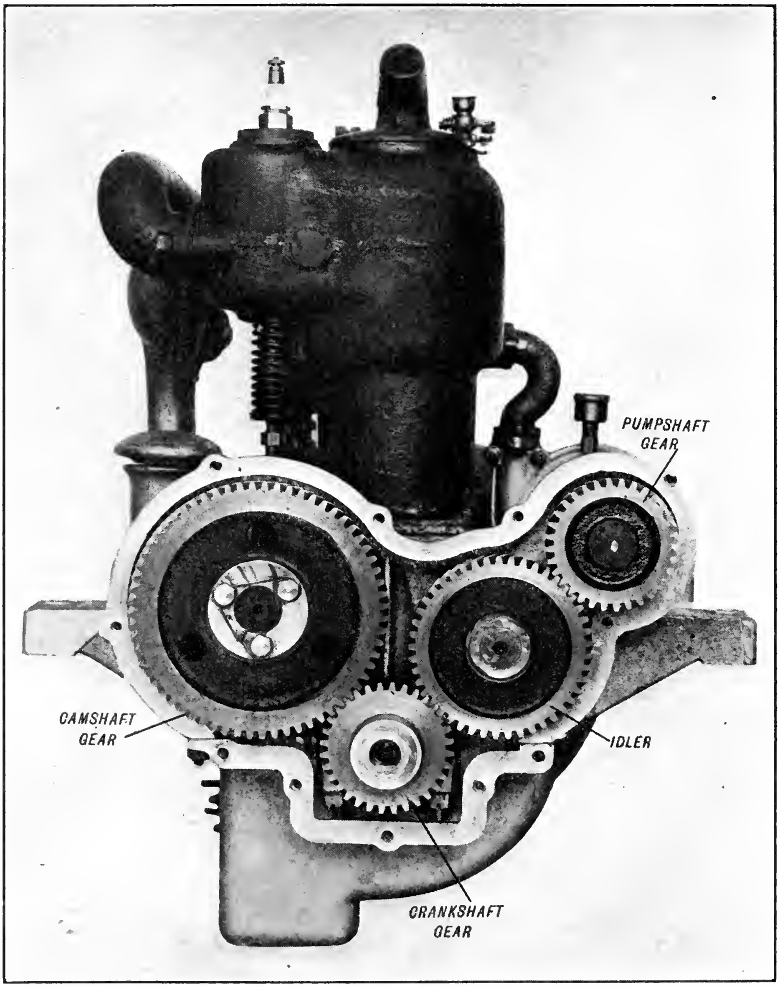


Fig. 80.—Front View of Warren-Detroit "30" Motor with Timing Gear Case Cover Removed to Show Arrangement of Cam Shafts and Water Pump Driving Gears.

At Fig. 81, B, the silent chain drive on the White & Poppe engines is shown. This installation is similar in the main to that previously described, and further description is not needed. The advantages cited for the application of chains are, first, silent operation which obtains even after the chains have worn considerably; second, in designing it is not necessary to figure on maintaining certain absolute center distances between the crank shaft and cam shaft sprockets,

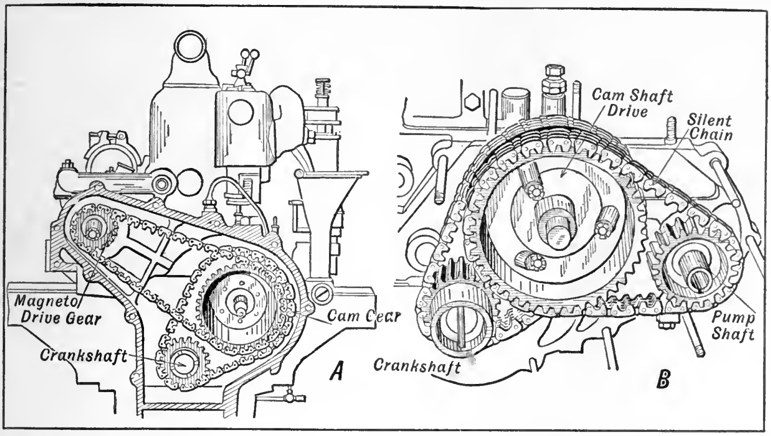


Fig. 81.—Showing Use of Silent Chain Connection Between Crank Shaft and Cam Shaft, and also for Driving Water Pump and Magneto Shafts. A—Chain Drive on Wolseley (English) 1912 Motor. B—Method of Using Silent Chains on White & Poppe (English) Power Plant.

as would be the case if conventional forms of gearing were used. On some forms of motor employing gears, three and even four members are needed to turn the cam shaft. With a chain drive but two sprockets are necessary, the chain forming a flexible connection which permits the driving and driven members to be placed at any distance apart that the exigencies of the design demand. When chains are used it is advised that some means for compensating chain slack be provided or the valve timing will lag when chains are worn. Many combination drives may be worked out with chains that would not be possible with other forms of gearing. It is expected that there will be a gradual tendency on the part of American designers to incorporate the silent chain drive in their product.

Valve Springs.—Another consideration of importance is the use of proper valve springs, and particular care should be taken with those of automatic valves. The spring must be weak enough to allow the valve to open when the suction is light and must be of sufficient strength to close it in time at high speeds. It should be made as large as possible in diameter and with a large number of convolutions, in order that fatigue of the metal be obviated, and it is imperative that all springs be of the same strength when used on a multiple-cylinder engine. On the exhaust valve the spring must be strong enough so that the valve will not be sucked in on the inlet stroke. It should be borne in mind that if the spring is too strong a strain will be imposed on the valve-operating mechanism and a hammering action produced which may cause deformation of the valve seat. Only pressure enough to insure that the operating mechanism will follow the cam is required. It is common practice to make the inlet and exhaust valve springs of the same tension when the valves are of the same size and both mechanically operated. This is done merely to simplify manufacture and not because it is necessary for the inlet valve spring to be as strong as the other.

Piston and Rotary Valve Motors.—Mention has been previously made of the interest obtaining in various forms of valves which permit more silent operation than the conventional poppet type. The main features of the Knight engine and its advantages have been considered, but a more complete description of the valve action may be timely. The sectional view through the cylinder at Fig. 82 shows the Knight sliding sleeves and their actuating means very clearly. The diagrams at Fig. 83 show graphically the sleeve movements and their relation to the crank shaft and piston travel. At A the piston has reached the top of the exhaust stroke and the exhaust port is barely open. The inlet port is just beginning to open. At B the piston is about two-thirds down on the inlet stroke and the inner sleeve has moved down, this bringing the two ports in alignment. This movement of the sleeve has closed off the exhaust port. At C the position of the sleeves at the end of the intake stroke is shown. The inner sleeve continues to go up, the outer sleeve is still moving down. Here we see the inlet port is almost closed; the exhaust port entirely so. D represents the position assumed by the sleeves at the end of the compression stroke, both ports are closed and the compressed charge is ready for ignition. At E the piston has covered about three-quarters of the power stroke

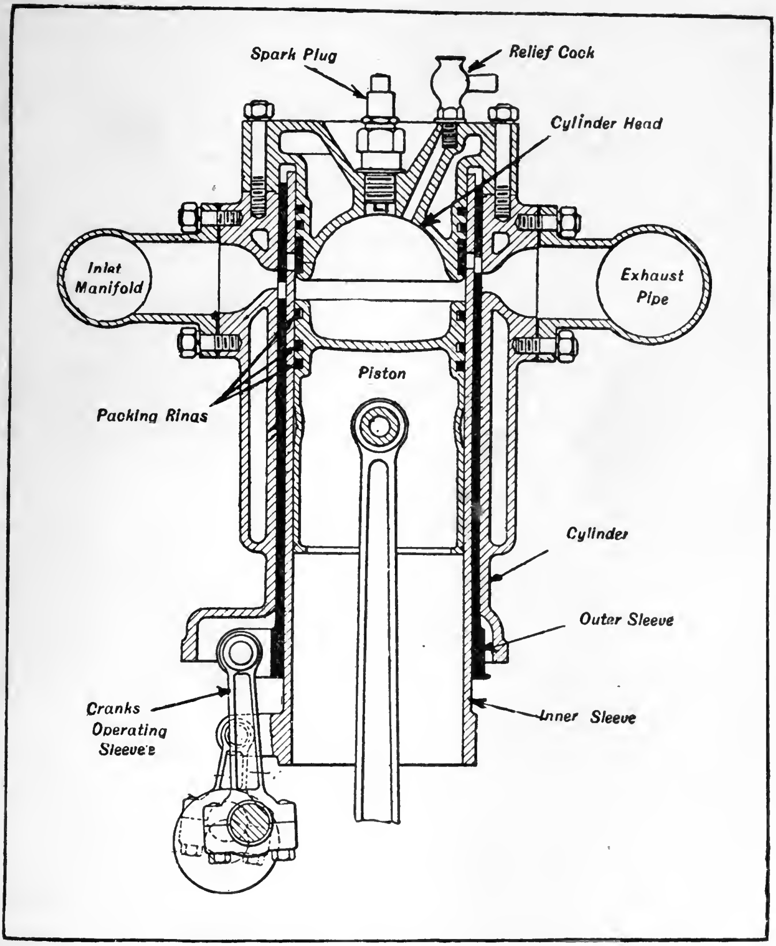


Fig. 82.—Section Through Cylinder of Knight Motor, Showing Important Parts of Valve Motion.

and the exhaust port begins to open. Both sleeves are now traveling down. At F the piston has reached the bottom of the power stroke and the exhaust port is almost fully opened. At G the piston is moving upward and the burned gas is being discharged through the fully opened exhaust port. At H the piston has started down on the intake stroke. The exhaust port is fully closed and the inlet port is just be-

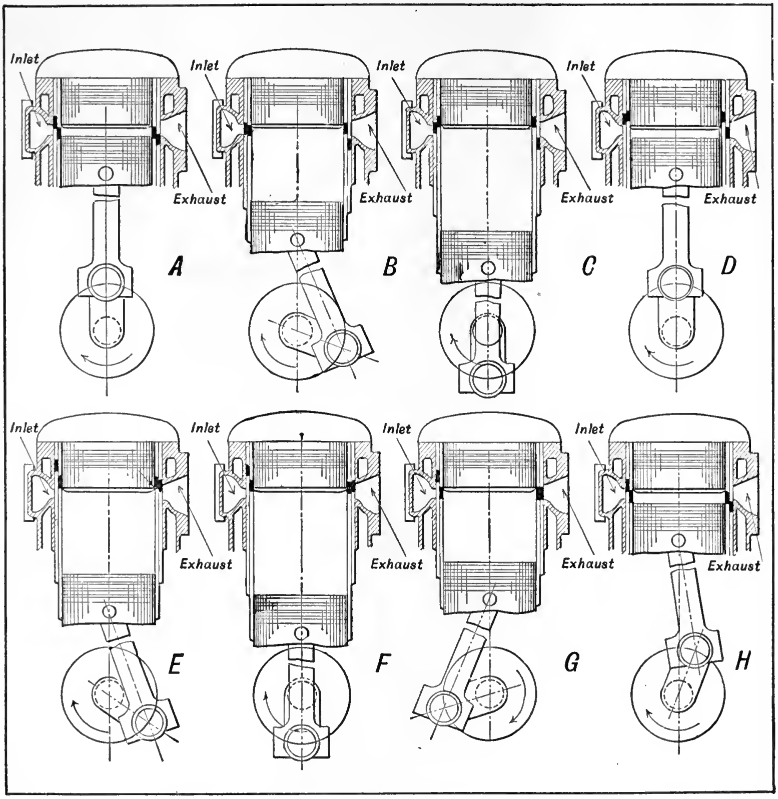


Fig. 83.—Diagram Showing Relative Movement of Sleeves and Cam Shaft of Knight Type Motor. Note Port Opening at Various Piston Positions. Shaded Portions of Sleeves Represent Ports.

ginning to open. The action may be summed up as follows: The inlet port begins to open when the lower edge of the opening of the outside sleeve which is moving down passes the top of the slot in the inner member also moving downwardly. The inlet port is closed when the lower edge of the slot in the inner sleeve which is moving up passes the top edge of the port in the outer sleeve which is also moving toward the top of the cylinder. The inlet opening extends over two hundred degrees of crank motion. The exhaust port is uncovered slightly when the lower edge of the port in the inner sleeve which is moving down passes the lower edge of the portion of the cylinder head which protrudes in the cylinder. When the top of the port in the outer sleeve traveling toward the bottom of the cylinder passes the lower edge of the slot in the cylinder wall the exhaust passage is closed. The exhaust opening extends over a period corresponding to about two hundred and forty degrees of crank motion.

The Valveless Miesse Engine.—The title given to this engine is hardly correct as it is not a valveless engine, but, as a glance at the illustration Fig. 84 will show, it is a combination of the single sleeve and piston valve forms. In the views presented, B is the single sleeve in which the port D is formed; A is the inlet and E the exhaust opening. The part designated by C is termed the "distribution" piston. Both the inlet and exhaust passages open into and lead from the small cylinder in which the piston C reciprocates. This, as well as the sleeve B, derives its motion from the cam or valve shaft through connecting rods. But little explanation is necessary to describe the operation of the valves and their effect. At A the relative positions of the sleeve and piston valve during the induction stroke are shown. It will be seen that the port D in the sleeve coincides with the slot in the cylinder proper, and the piston valve C is in such position that while the mixture has free access from A to the cylinder the exhaust port E is cut off therefrom. At B the relative positions of the sleeve and piston valve during the explosion stroke are shown. The port D in the sleeve has moved up above the opening in the cylinder wall while the latter is there closed against any possible escape of gas by the cylindrical head of the piston valve C. The position of the parts on the exhaust stroke are shown at C. The piston valve has risen still further, closing the induction passage A which leads the fresh gases to the cylinder and at the same time has made it possible for the exhaust products to be discharged beneath it through the opening E which is in connection with the exhaust manifold.

The advantages claimed for this design are the use of a single sleeve, cooling of the sleeve cylinder ports and piston valve by the incoming mixture on the induction stroke and the protection of the

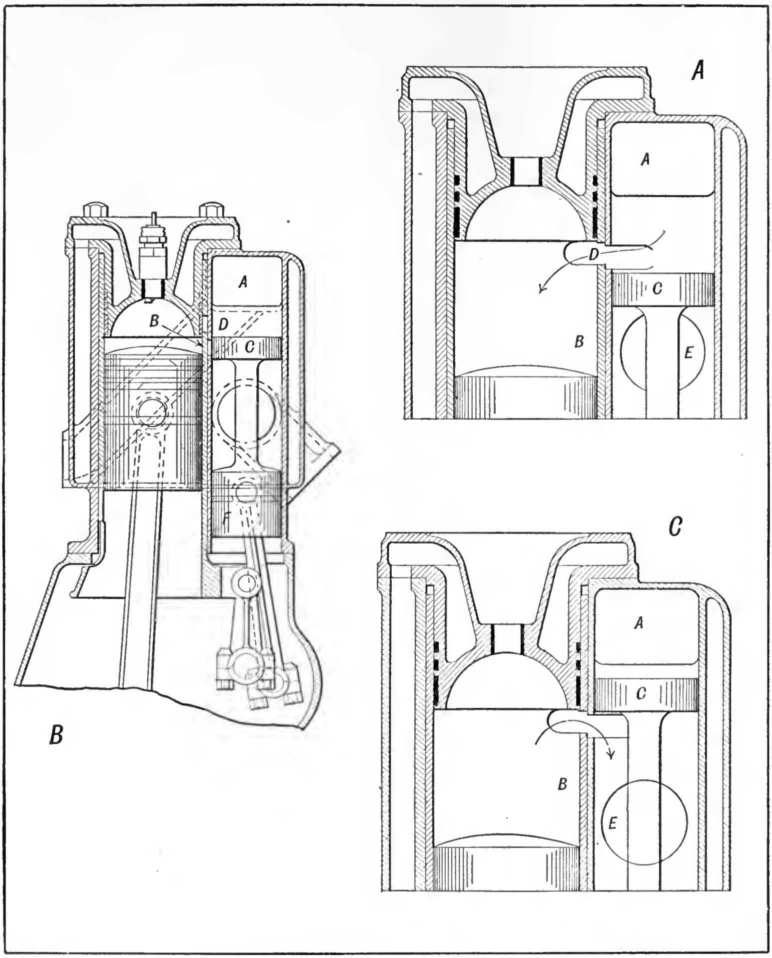


Fig. 84.—Sectional Views Showing Action of Miesse Combination Sleeve and Piston Valve at Different Points in Cycle of Engine Operation.

piston valve from contact with the exploded charge during the power stroke. It is said that the exhaust gases are discharged through the lower orifice rather than the upper one in order that no pressure be exerted upon the head of the piston and upon its connecting rod and crank pin bearings. By passing the exhaust gases which have considerable pressure between the upper and lower portions of the piston valve the latter is balanced during exhaust period by the products of the combustion under pressure. The valve shaft, which is the small auxiliary crank shaft reciprocating the sleeve and piston, is supported on five bearings and is driven by a silent chain connection from the main crank shaft.

The Itala Rotary Valve Motor.—A type of rotary valve which is said to be efficient is depicted at Fig. 85. This is used in the Itala engine and has features of merit. This motor does not differ much in appearance from the ordinary poppet valve type. The cylinders are cast in pairs with a projection at one side which acts as a cylinder for the valve. Provision is made for water circulation around this chamber and the valve is also formed in such a way that water may be circulated through it. But two valves are employed, one for each pair of cylinders, and these two members take the place of the eight valves used on the poppet engine. The valve driving shaft, which is placed similar to the conventional cam shaft, turns the vertical shaft to which the valves are attached by helical gears. There is but one port in each cylinder which provides the means of communication between the valves and combustion chamber, this alternately serving the purpose of inlet and exhaust port. The manifolds are on opposite sides of the engine. The gas enters the base of each valve chest and the inert products pass from the top of the valve chamber by a peculiar cored passage in the cylinder casting. The rotary valve is made of cast iron and carries a number of packing rings. Each valve has four vertical openings; two for the fresh gases, the others for the burned product. These openings are arranged so that there is one inlet and one exhaust port registering with the openings in the respective cylinders. The exhaust ports are wider than the inlet openings, because a longer period of opening is required for the exhaust.

The views at Fig. 85 show the operation of the valve clearly. A depicts its position at the beginning of the intake stroke, the fresh gas entering from the bottom passes through the interior of the valve and into the combustion chamber. The smaller sectional views show a

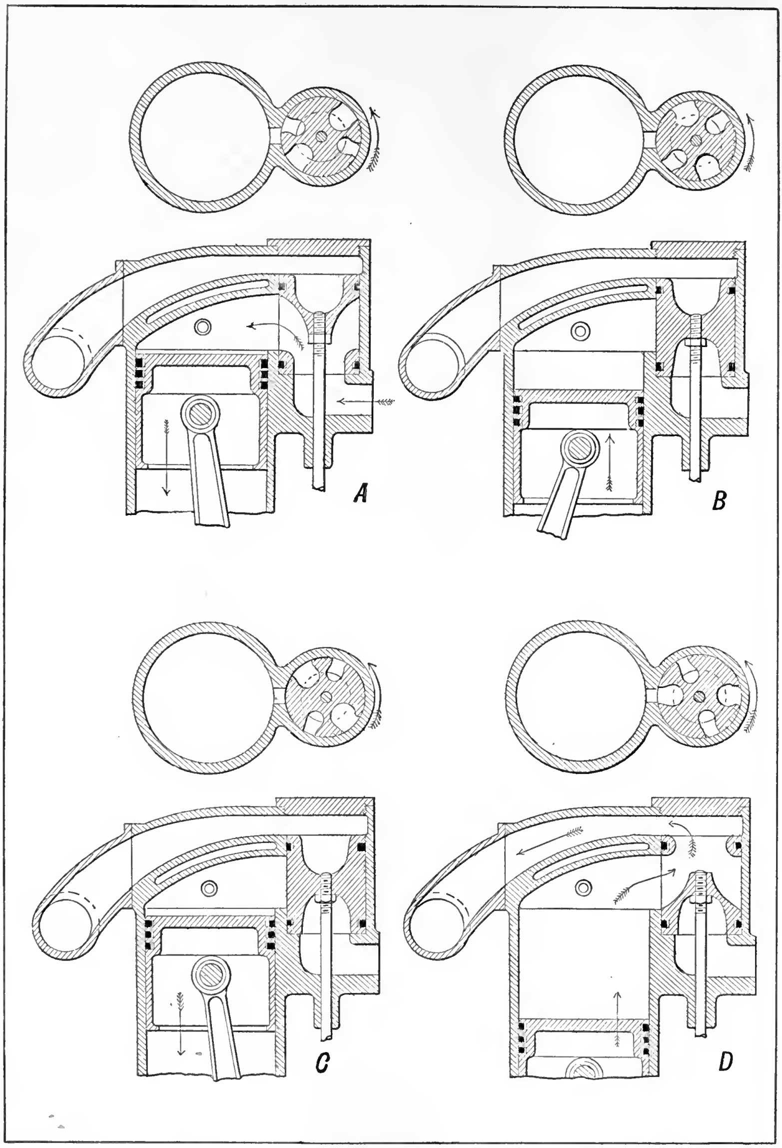


Fig. 85.—Defining Action of Peculiar Rotary Valve Used in Latest Itala (Italian) Motor.

plan of the cylinder and valve chest. Referring to these it will be seen that the valve which is rotating in the direction of the arrow is just beginning to uncover the port in the cylinder. At B conditions during the compression stroke are shown. The port in the cylinder is

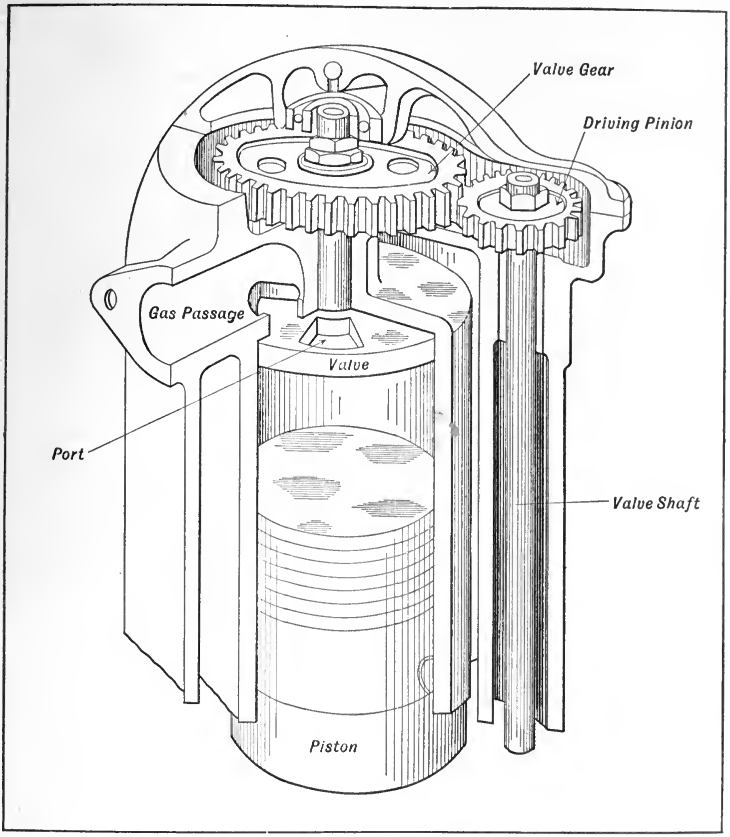


Fig. 86.—Partial Section of Reynolds Rotary Valve Motor Cylinder, Showing Method of Rotating Simple Disk Valve and Ports in Cylinder Head.

closed by the solid wall of the valve. At C the position of the valve during the power stroke is shown. It will be observed that the opening in the cylinder is still closed by the valve wall. At D the conditions during the exhaust stroke are outlined. The valve has revolved so that the exhaust port therein is in communication with the exhaust pipe at the top of the cylinder and the port of the combustion chamber. This permits the inert gases to leave the cylinder freely. Careful study of the drawings will show that the gas flow is easy and that there are no sharp corners to impede the gases as they enter or leave the cylinders.

The Reynolds Rotary Valve Motor.—The Reynolds motor, a sectional view through one of its cylinders being shown at Fig. 86, has not been used to any extent in automobile service, but has proven thoroughly practical in marine applications. The valve consists of a flat disk seating directly against the top of the combustion chamber. It is turned by a shaft which extends through a boss on top of the cylinder head and which is driven direct from the crank shaft by gearing at half the motor speed. The valve has a port cut into it of the keystone shape, clearly shown in illustration, this registering successively with openings in the cylinder head. The valve mechanism is said to be very quiet, and, as will be seen at Fig. 87, the motor is a very compact design. A disadvantage is cited that the force of the explosion keeps the valve disk tight against the seat, this tending to cause considerable resistance to its motion. It is claimed that no difficulty is experienced from this source, and that an oil film is maintained positively between the valve disk and its seat so that it turns with minimum friction.

Other Rotary Valve Types.—Various other forms employing rotary valves have been devised, and some of these which are said to have been used in a practical way are shown at Fig. 88. That at A is known as the Mead. This is a four-cylinder motor with two long cylindrical valves extending along opposite sides of the cylinders in close connection with the combustion chamber. These cylinders have ports cut through them at distances equal to the center line of the cylinders and are suitably spaced so that the ports in the cylinders are uncovered in proper succession. One of the drums serves to control the inlet ports; the other regulates the exhaust openings. The valves are driven at one-quarter crank-shaft speed by suitable gearing.

The type shown at B is a French design which differs from the Reynolds motor previously described only in the shape of the rotary valve member which is conical instead of flat. The parts are shown as follows: A is the rotary valve member; B is the gas passage, and D is a port in the valve member. The small view presented below the vertical section is a plan showing the disposition of the ports. The

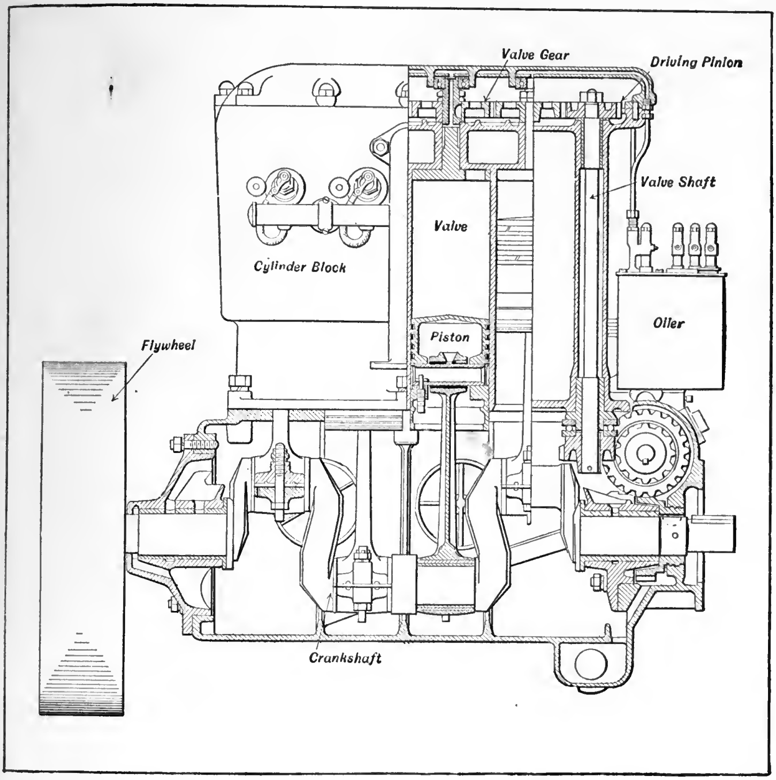


Fig. 87.—Part Section of Reynolds Rotary Valve Motor, Showing Practical Application of Ported Disk in Controlling Gas Passages. Note Compact Design of Cylinder Block and Two-Bearing, Four-Throw Crank Shaft.

same lettering applies as above. If the cone turns in the direction of the arrow, B is the exhaust port and C the intake port, while D represents the opening in the valve. The form shown at C is a modification of that depicted at B. Two conical valves are used instead of one,

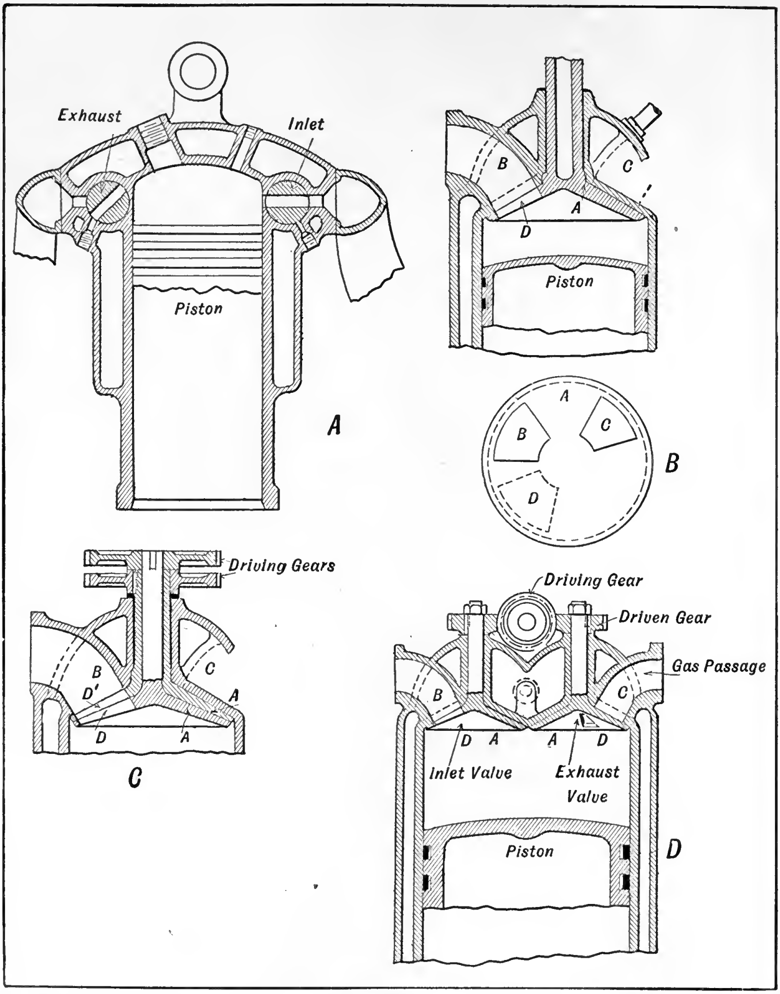


Fig. 88.—Unconventional Forms of Rotary Valve Motors Designed to Meet the Present Day Demand for Silent Valve Action. A—Mead Motor Using Two Revolving Cylindrical Valves, One at Each Side of Cylinder. B—Single Ported Cone Valve. C—Application of Two Single Ported Cones, One Superposed. D—Use of Distinct Valves, One for Inlet Port, the Other to Govern Exhaust Passage.

these being turned in opposite directions by suitable gears. It is claimed that this gives a more rapid port opening than when a single valve is employed. Sometimes when two conical valve members are used they are placed side by side, as shown at D, one of these serving exclusively for the exhaust; the other for the inlet. The objection to this construction is that owing to the smaller size of the cone the ports are more limited in area than when a single valve member is employed.

The Sphinx Ring Valve Motor.—One of the designs which has been used successfully and which employs a ring valve in place of the usual poppet valves is called the Sphinx motor. It is claimed that all the advantages of the sliding sleeve types are obtained with much less complication. In this motor a split ring reciprocated by a bell crank serves to uncover the intake and exhaust ports. The construction of this member, as well as the actuating bell crank, return spring and cam shaft are clearly shown at Fig. 89. In the cylinder walls, and near the head, two annular chambers are provided, these forming the intake and exhaust ports. Within the cylinder is a split ring having sufficient face depth to cover both the intake and exhaust ports, but having the necessary reciprocating motion to allow it to uncover either one or the other of the ports as required to insure the admission of the fuel and the discharge of the spent gases. In its central position, shown at Fig. 89, B and C, the split ring covers the two ports, providing a gas-tight chamber; on being moved down, as depicted at A, it uncovers the intake port and closes the exhaust, and on being raised, as outlined at D, it opens the exhaust and closes the intake.

Being split, its extensibility assures gas-tightness, the degree of tightness being in proportion to the pressure in the cylinder, while leakage around the ports is impossible at any time. Its movement is slight, being less than one inch for a motor of 3.9-inch by 5.5-inch bore and stroke, and the intake port being above the ring, this latter is swept by the fresh, cool gases at every induction stroke and consequently maintained at a moderate temperature.

This design particularly lends itself to an easily produced and clean monobloc casting, and has the further advantage of giving a compact combustion chamber without pockets and with unusually large valve area. On the ordinary type of motor with valves on one or both sides any increase in the valve diameter involves a proportional increase in the size of the pocket with a decrease of thermal efficiency.

The split sliding ring, or sleeve, which in the "Sphinx" replaces the pair of poppet valves of the ordinary motor, and the costly concen-

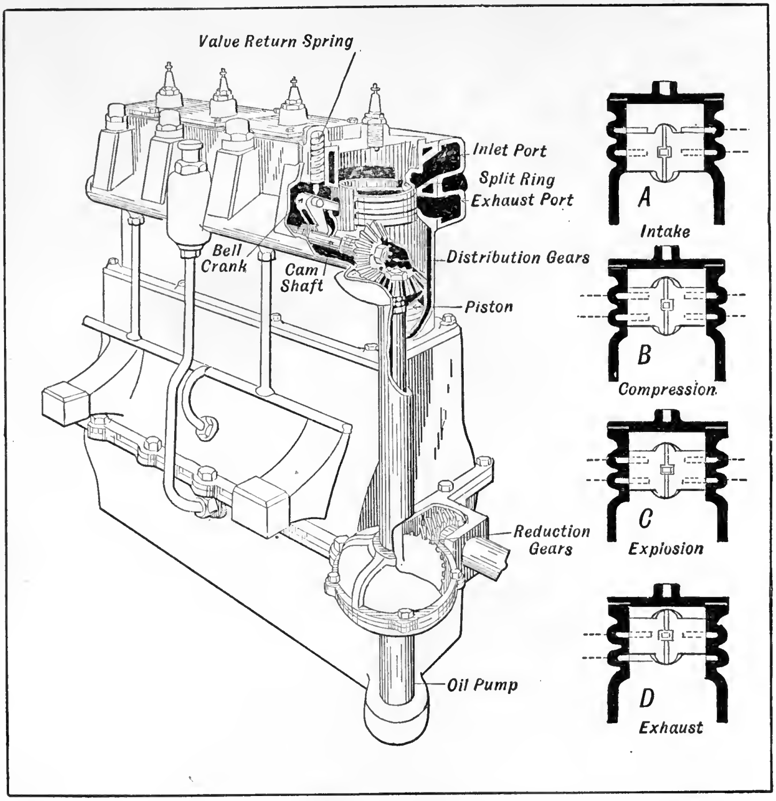


Fig. 89.—Part Section of Sphinx Valveless Motor in which Poppet Valves are Replaced by a Split Ring which Reciprocates in the Cylinder Head, Opening and Closing the Gas Ports as it Moves Up and Down. A—Inlet Ports Open. B and C—All Ports Closed. D—Exhaust Ports Open.

tric sleeves in motors of the sliding valve type, is shown in Fig. 89. It is a gray iron casting, having a face depth of one and a half inches for a motor of 3.9-inch by 5.5-inch bore and stroke, and provided with a hollow spindle or bearing block for the rocker arm. As will be seen from the illustration, the depth of the ring is greater around the hollow spindle than at any other point, this increased depth being necessary to cover the port through which the rocker arm is passed from the outside to the inside of the cylinder. The face depth at this point is sufficient to assure the covering of this port whatever the position of the split ring; in other words, this slot in the cylinder wall is never uncovered.

By means of a bell crank, the long arm of which operates in the socket of the ring valve, and an ordinary type of cam shaft the necessary reciprocating motion of the ring is obtained to allow the different phases of a four-cycle motor. One of the most valuable features of this motor is the large valve area obtainable without the complication attending the use of large diameter poppet valves and without the big pockets necessary with motors of the " L " or " T " type.

The poppet valve spring must be of sufficient strength to correctly seat the valve at high motor speeds. If a weak spring is used it will not have time to return the valve to its seating before it will be again lifted by the cam and there is loss of power. The spring used on the " Sphinx " motor need only be strong enough to balance the weight of the split ring, for it is only responsible for its return and in no way for its proper seating. Further, as each upward movement of the ring is followed by the induction stroke of the motor, the work of the spring is relieved by the inrushing of the gases. In other words, the suction of the gas around the ring tends to draw it down, just as an automatic intake valve is drawn down on the suction stroke of the motor. The spring, then, need only be sufficiently strong to keep the roller in contact with the face of the cam, and as it is carried in an independent housing and not subjected to a high temperature, its life is practically indefinite.

Darracq Rotary Distributor Motor.—In the Darracq power plant which is shown at Fig. 90, the gases enter through a rotary member of D section, which is placed horizontally along the side of the cylinder head and parallel with the crank shaft. This distributor is approximately two-thirds the diameter of the cylinder and revolves on large annular ball bearings, one placed at each end. One member serves to control both intake and exhaust openings. This is accomplished by providing the barrel-shaped chamber in which the valve revolves with three ports for each cylinder. One of these provides communication between the valve case and the combustion chamber, the others serve for intake and exhaust passages.

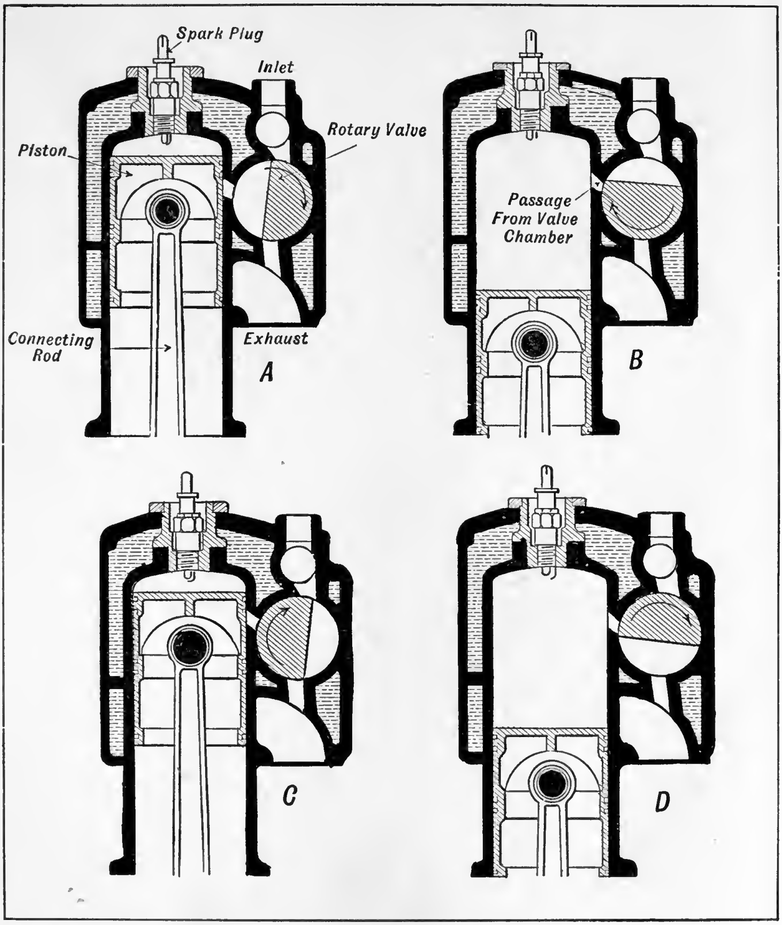


Fig. 90.—Diagram Illustrating Action of Darracq (French) D Form Rotary Valve Motor. A—Piston at Beginning of Induction Stroke. B—Piston at Inception of Compression Stroke. C—Piston in Position for Receiving Explosion Impact. D—Valve Position at Start of Exhaust Period.

As the valve rotates the cylinder is placed in communication with either the intake or exhaust passages and the valve is driven by suitable gearing at one-half the engine speed, as is the case with the conventional cam shaft. The various valve positions are clearly shown at Fig. 90. A corresponds to the suction stroke; and the piston is shown starting to uncover the port leading from the valve chamber into the cylinder. The rotary valve is also uncovering the intake port. By the time the top of the piston reaches the bottom of the passage communicating between combustion and valve chambers, the inlet opening is uncovered and the gas rushes into the cylinder. At B it will be seen that the valve has closed the passage leading from the cylinder, and as the piston rises, the gas previously inspired is compressed. The position of the piston when it has reached the end of the compression stroke is shown at C. At this position the compressed charge is ignited. It will be noted that the piston covers the port leading into the valve chamber, and that the valve is thus protected from the direct heat of combustion. At D the position of the valve at the inception of the exhaust stroke is shown, and it is about to uncover the port leading from the cylinder to the valve chamber and permit the exhaust gases to flow out through suitable openings. The heat evolved during the first intervals of the explosion, at which point the maximum temperature obtains, is kept from the valve and simplifies the problem of lubrication. It will be evident that with this construction a small portion of the inert gases are retained in the combustion chamber, but it is claimed by those favoring this construction that this does not constitute as serious defect in practice as theoretical considerations might indicate.

The Hewitt Piston Valve Motor.—A type of motor in which true piston valves are used successfully is shown in section at Fig. 91. This is the Hewitt, a pioneer form of English derivation. Two piston valves are provided for each cylinder; one for the intake, the other to regulate the exhaust passage. They are placed adjacent to each other on the same side of the motor, and are inclined toward the top. A small crank shaft revolving at one-half the speed of the main crank shaft is employed to operate the piston. Each of these piston valves are simply smaller trunk pistons similar in type to those used in the cylinder proper, reciprocating in their distinct small water-cooled cylinder. Piston rings of the conventional pattern are used to maintain a gas-tight joint, as is the case with the main piston. The fresh gas manifold is coupled to the side of one valve cylinder and the exhaust piping with the side of the other valve chamber. The timing of both intake and exhaust valves is such that they receive a portion of the explosive impulse, which drives them downward and tends to make them partially self - operating. When the explosion occurs, both valve pistons are at the top of their cylinders and receive part of the impact. On the compression stroke both pistons move up, the exhaust member moving ahead of the other. The piston valves are lubricated by splash just as the main piston chamber. These pistons have comparatively long stroke, about two-thirds that of the working piston. The various piston positions during the cycle of operation are clearly shown in diagrams at Fig. 92, the valves being shown at opposite sides of the cylinder to make their action clearer. At A the main piston is part way down on the intake stroke, and the inlet piston has uncovered the slots leading from the gas manifold to the combustion chamber. The exhaust is fully closed. At B the main piston is starting to go up on the compression stroke and both inlet and exhaust ports are fully closed by their respective pistons. At C the explosion has taken place and the three pistons are being driven down in the

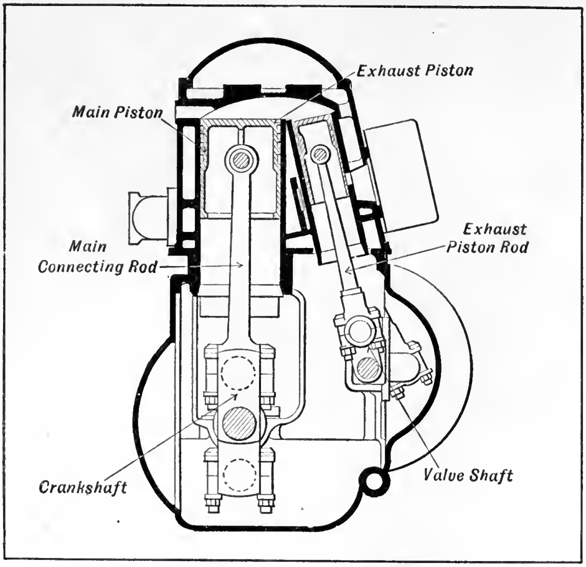


Fig. 91.—Section of Hewitt Piston Valve, Motor Cylinder and Valve Chest.

directions indicated by the arrow. At D the exhaust piston has uncovered the series of holes which provide communication between the combustion chamber and the manifold, while the inlet piston covers fully the slots it controls. It is claimed that this four-cylinder piston valve motor has superior torque to that obtained from a similar power plant using poppet valves.

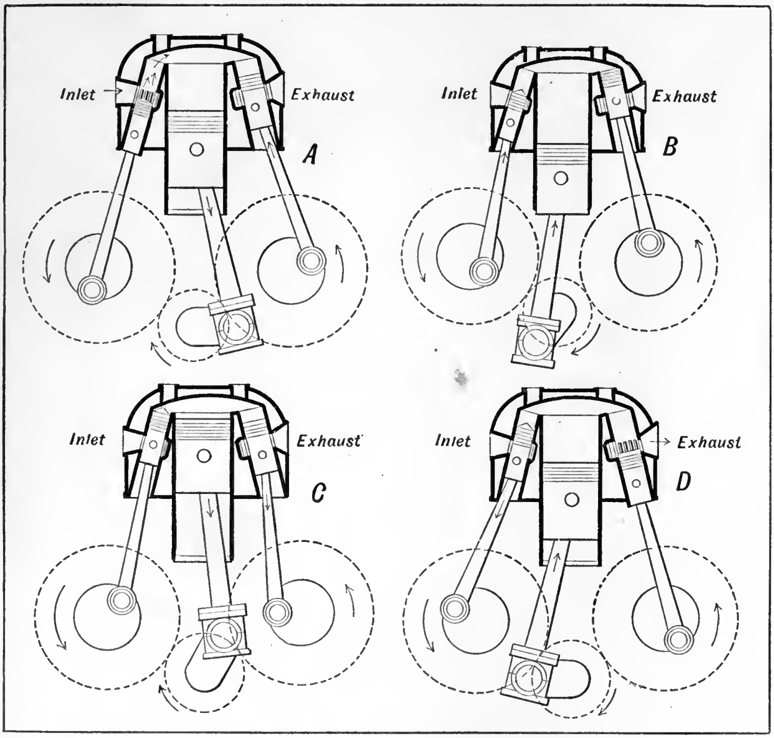


Fig. 92.—Hewitt Piston Valve Motor Action Outlined Graphically. A—Suction Stroke. B—Compression. C—Explosion. D—Exhaust.

Valve Timing.—It is in valve timing that the greatest difference of opinion prevails among engineers and it is rare that one will see the same formula in different motors. It is true that the same timing could not be used with motors of different construction, as there are many factors which determine the amount of lead to be given to the valves. The most important of these is the relative size of the valve to the cylinder bore, the speed of rotation it is desired to obtain, the fuel efficiency, the location of the valves, and other factors too numerous to mention.

Most of the readers should be familiar with the cycle of operation of the internal combustion motor of the four-stroke type, and it seems unnecessary to go into detail except to present a review. The first stroke of the piston is one in which a charge of gas is taken into the motor; the second stroke which is in reverse direction to the first is a compression stroke, at the end of which the spark takes place, exploding the charge and driving the piston down on the third or expansion stroke, which is in the same direction as the intake stroke, and finally, after the piston has nearly reached the end of this stroke, another valve opens to allow the burned gases to escape, and remains open until the piston has reached the end of the fourth stroke and is in a position to begin the series over again. The ends of the strokes are reached when the piston comes to a stop at either top or bottom of the cylinder and reverses its motion. That point is known as a center and there are two for each cylinder, top and bottom centers, respectively.

All circles may be divided into 360 parts, each of which is known as a degree, and in turn each of these degrees may be again divided into minutes and seconds, though we need not concern ourselves with anything less than the degree. Each stroke of the piston represents 180 degrees travel of the crank, because two strokes represent one complete revolution or three hundred and sixty degrees. The top and bottom centers are therefore separated by 180 degrees. Theoretically each phase of a four-cycle engine begins and ends at a center, though in actual practice the inertia or movement of the gases makes it necessary to allow a lead or lag to the valve, as the case may be. If a valve opens before a center, the distance is called "lead"; if it closes after a center, this distance is known as "lag." The profile of the cams ordinarily used to open or close the valves represents a considerable time in relation to the 180 degrees of the crank-shaft travel, and the area of the passages through which the gases are admitted or exhausted is quite small owing to the necessity of having to open or close the valves at stated times; therefore, to open an adequately large passage for the gases it is necessary to open the valves earlier and close them later than at centers.

That advancing the opening of the exhaust valve was of value was discovered on the early motors and is explained by the necessity of releasing a large amount of gas, the volume of which has been greatly raised by the heat of combustion. When the inlet valves were mechanically operated it was found that allowing them to lag at closing enabled the inspiration of a greater volume of gas. Disregarding the inertia or flow of the gases, opening the exhaust at center would enable one to obtain full value of the expanding gases the entire length of the piston stroke, and it would not be necessary to keep the valve open after the top center, as the reverse stroke would produce a suction effect which might draw some of the inert charge back into the cylinder. On the other hand, giving full consideration to the inertia of the gas, opening the valve before center is reached will provide for quick expulsion of the gases, which have sufficient velocity at the end of the stroke, so that if the valve is allowed to remain open a little longer, the amount of lag varying with the opinions of the designer, the cylinder is cleared in a more thorough manner.

Blowing Back.—When the factor of retarded opening is considered without reckoning the inertia of the gases it would appear that, if the valve were allowed to remain open after center had passed say on the closing of the inlet, the piston having reversed its motion would have the effect of expelling part of the fresh charge through the still open valve as it passed inward at its compression stroke. This effect is called blowing back and is often noted with motors where the valve settings are not absolutely correct, or where the valve springs or seats are defective and prevent proper closing.

This factor is not of as much import as might appear, as on closer consideration it will be seen that the movement of the piston as the crank reaches either end of the stroke is less per degree of angular movement than it is when the angle of the connecting rod is greater. Then again a certain length of time is required for the reversal of motion of the piston, during which time the crank is in motion but the piston practically at a standstill. If the valves are allowed to remain open during this period, the passage of the gas in or out of the cylinder will be by its own momentum.

Lead Gives Exhaust Valve.—The faster a motor turns, all other things being equal, the greater the amount of lead or advance it is necessary to give the opening of the exhaust valve. It is self-evident truth that if the speed of a motor is doubled, it travels twice as many degrees in the time necessary to lower the pressure. As most designers are cognizant of this fact the valves are proportioned accordingly. It is well to consider in this respect that the cam profile has much to do with the manner in which the valve is opened, that is, the lift may be abrupt and the gas allowed to escape in a body, or the opening may be gradual, the gas issuing from the cylinder in thin streams. An analogy may be made with the opening of any bottle which contains liquid highly carbonated. If the cork is removed suddenly the gas escapes with a loud pop, but on the other hand, if the bottle is uncorked gradually, the gas escapes from the receptacle in thin streams around the cork, and passage of the gases to the air is accomplished without noise. While the second plan is not harsh, it is slower than the former, as must be evident.

Exhaust Closing, Inlet Opening.—A point which has been much discussed by engineers is the proper relation of the closing of the exhaust valve and the opening of the inlet. Theoretically they should succeed each other, the exhaust closing at upper dead center and the inlet opening immediately afterward. The reason why a certain amount of lag is given the exhaust closing in practice is that the piston cannot drive the gases out of the cylinder unless they are compressed to a degree in excess of that existing in the manifold or passages, and while toward the end of the stroke this pressure may be feeble, it is nevertheless indispensable. At the end of the piston's stroke, as marked by the upper dead center, this compression still exists, no matter how little it may be, so that if the exhaust valve is closed and the inlet opened immediately afterward, the pressure which exists in the cylinder may retard the entrance of the fresh gas and a certain portion of the inert gas may penetrate into the manifold. As the piston immediately begins to aspirate this may not be serious, but as these gases are drawn back into the cylinder the fresh charge will be diluted and weakened in value. If the spark plug is in a pocket the points may be surrounded by this weak gas, and the explosion will not be nearly as energetic as when the ignition spark takes place in pure mixture.

It is a well-known fact that the exhaust valve should close after dead center and that a certain amount of lag should be given to opening of the inlet. The lag given the closing of the exhaust valve should not be as great as that given the closing of the inlet valve. Assuming that the excess pressure of the exhaust will equal the depression during aspiration, the time necessary to complete the emptying of the cylinder will be proportional to the volume of the gas within it. At the end of the suction stroke the volume of gas contained in the cylinder is equal to the cylindrical volume plus the space of the combustion chamber. At the end of the exhaust stroke the volume is but that of the dead space, and from one-third to one-fifth its volume before compression. While it is natural to assume that this excess of burned gas will escape faster than the fresh gas will enter the cylinder, it will be seen that if the inlet valve were allowed to lag twenty degrees, the exhaust valve lag need not be more than five degrees, providing that the capacity of the combustion chamber was such that the gases occupied one-quarter of their former volume.

It is evident that no absolute rule can be given, as back pressure will vary with the design of the valve passages, the manifolds, and the construction of the muffler. The more direct the opening, the sooner the valve can be closed and the better the cylinder cleared. Ten degrees represent an appreciable angle of the crank and the time required for the crank to cover this angular motion is not inconsiderable and an important quantity of the exhaust may escape, but the piston is still very close to the dead center after the distance has been covered.

Before the inlet valve opens there should be a certain depression in the cylinder, and considerable lag may be allowed before the depression is appreciable. So far as the volume of fresh gas introduced during the admission stroke is concerned, this is determined by the displacement of the piston between the point where the inlet valve opens and the point of closing, assuming that sufficient gas has been inspired so that an equilibrium of pressure has been established between the interior of the cylinder and the outer air. The point of inlet opening varies with different motors. It would appear that a fair amount of lag would be fifteen degrees past top center for the inlet opening, as a certain depression will exist in the cylinder, assuming that the exhaust valve has closed five or ten degrees after center, and at the same time the piston has not gone down far enough on its stroke to materially decrease the amount of gas which will be taken into the cylinder.

Closing the Inlet Valve.—As is the case with the other points of opening and closing, there is a wide diversity of practice as relates to closing the inlet valve. Some of the designers close this exactly at bottom center, but this practice cannot be commended, as there is a considerable portion of time, at least ten or fifteen degrees angular motion of the crank, before the piston will commence to travel any extent on its compression stroke. The gases rushing into the cylinder have considerable velocity, and unless an equilibrium is obtained between the pressure inside and that of the atmosphere outside, they will continue to rush into the cylinder even after the piston ceases to exert any suction effect.

For this reason, if the valve is closed exactly on center, a full charge may not be inspired into the cylinder, though if the time of closing is delayed, this momentum or inertia of the gas will be enough to insure that a maximum charge is taken into the cylinder. The writer considers that nothing will be gained if the valve is allowed to remain open longer than twenty degrees, and an analysis of practice in this respect would seem to confirm this opinion. From that point in the crank movement the piston travel increases and the compressive effect is appreciable, and it would appear that a considerable proportion of the charge might be exhausted into the manifold and carburetor if the valve were allowed to remain open beyond a point corresponding to twenty degrees angular movement of the crank.

Time of Ignition.—In this country engineers unite in providing a variable time of ignition, though abroad some difference of opinion is noted on this point. The practice of advancing the time of ignition, when affected electrically, was severely condemned by early makers, these maintaining that it was necessary because of insufficient heat and volume of the spark, and it was thought that advancing ignition was injurious. The engineers of to-day appreciate the fact that the heat of the electric spark, especially when from a mechanical generator of electrical energy, is the only means by which we can obtain practically instantaneous explosion, as required by the operation of motors at high speeds, and for the combustion of large volumes of gas.

It is apparent that a motor with a fixed point of ignition is not as desirable, in every way, as one in which the ignition can be advanced to best meet different requirements, and the writer does not readily perceive any advantage outside of simplicity of control in establishing a fixed point of ignition. In fact, there seems to be some difference of opinion among those designers who favor fixed ignition, and in one case this is located forty-three degrees ahead of center, and in another motor the point is fixed at twenty degrees, so that it may be said that this will vary as much as one hundred per cent in various forms. This point will vary with different methods of ignition, as well as the location of the spark plug or igniter. The writer favors a variable point of ignition, as this offers advantages which cannot be obtained with fixed ignition, and enables one to best gauge the requirements of the time of firing the charge by conditions of operation from time to time. The range may be as desired, varying from a point after center for starting to one forty-five degrees advanced for maximum speed. Then again, flexibility of control is greatly increased when spark time may be varied to suit requirements.

It is obvious by consideration of the foregoing that there can be no arbitrary rules established for timing, because of the many conditions which determine the best times for opening and closing the valves. It is customary to try various settings when a new motor is designed until the most satisfactory points are determined, and the setting which will be very suitable for one motor is not always right for one of different design.

A series of valve-timing diagrams are presented at Fig. 93, these showing the timing employed on four different engines of about the same size. In that outlined at A the inlet valve begins to open eight degrees after center and closes exactly on the bottom center. The exhaust opens thirty degrees before bottom center and closes five degrees after top center. This motor employs large valves placed in the head and does not need much lead of the exhaust opening. In the diagram shown at B the inlet valve has a lag of fourteen degrees on the opening and closes six degrees after bottom center. The exhaust valve opens forty-one degrees before bottom center. The timing method outlined at C gives a greater lead to the exhaust than any of the others shown. The exhaust valve starting to open forty-seven degrees before center and closing twelve degrees after top center. The inlet valve begins to open nine degrees after top center and lags seventeen degrees after bottom center. It will be

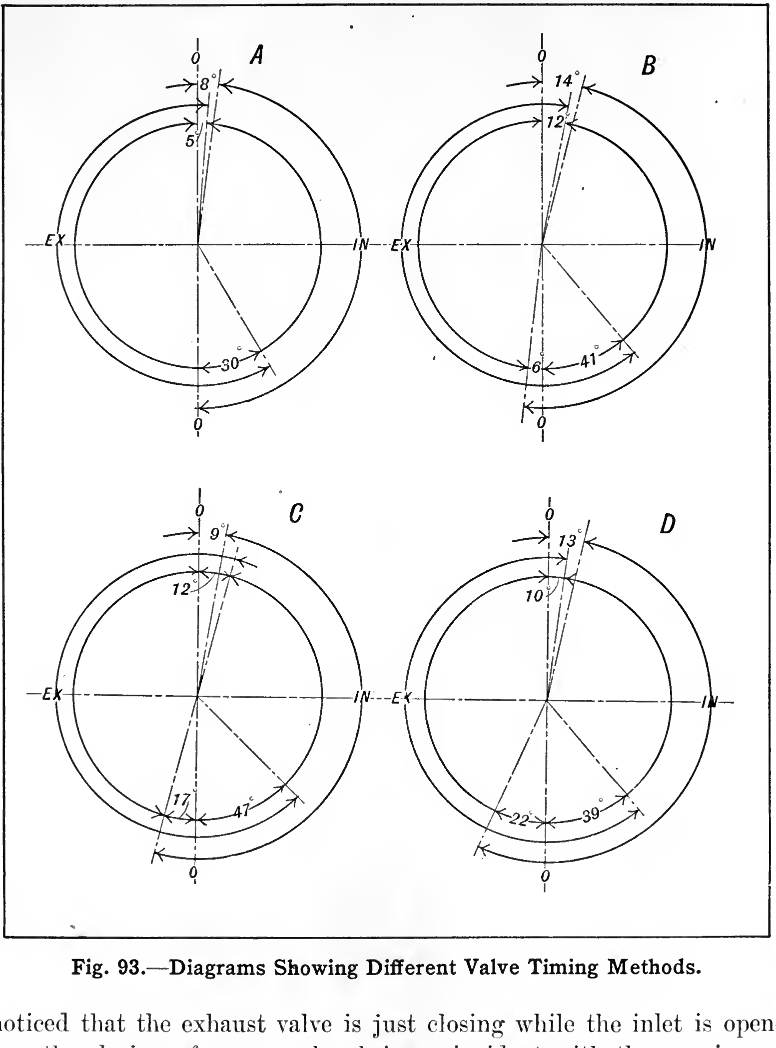


Fig. 93.—Diagrams Showing Different Valve Timing Methods.

noticed that the exhaust valve is just closing while the inlet is opening, the closing of one member being coincident with the opening of the other. This is not very often followed, because there is danger of the admixture of gases should anything interfere with prompt valve action.

The diagram shown at D does not differ very much from that shown at B, except in the lag of the inlet valve. This opens at thirteen degrees after top center and does not close until twenty-two degrees after bottom center. The exhaust valve opens thirty-nine degrees before bottom center and closes ten degrees after top center. It will be seen that at A there is a lapse of three degrees between exhaust valve closing and inlet valve opening. At B the lapse is two degrees. At C the timing arrangement is such that there is no lapse between exhaust closing and inlet opening. Practically as soon as the exhaust valve is closed fully the inlet valve has opened materially. At D the lapse between exhaust valve closing and inlet opening is three degrees. These methods of timing may be considered representative, though almost every designer follows his own preferences. Sometimes considerable experimenting is necessary before the point is reached where the motor runs with the maximum power and without noise.

The diagram at Fig. 94 shows clearly the method utilized in marking the fly wheel of a typical four-cylinder engine so that the valves may be properly timed without following piston or crank-shaft movement directly. The fly wheel, which is 15¾ inches in circumference, has been marked off as indicated. As this is a four-cylinder engine, the marks on the fly wheel enable one to time all cylinders, as one of two will fire when one mark corresponding to upper center coincides with the fixed indicating device on the center line of the crank case. The others explode in turn when the mark indicating the lower center registers with the trammel point, as the little indicating device on the crank case is called. When the diameter of a fly wheel is 15¾ inches, 2.062 inches measured from one of the center lines indicate the crank-pin travel of fifteen degrees. The lag of inlet closing which in this motor is thirty-three degrees is represented by a distance of 4.536 inches on the circumference of the fly wheel. The exhaust valve lead which is fifty-three degrees and thirty minutes is determined by measuring 7.353 inches ahead of the center lines. The point where the exhaust valve closes which is twelve degrees after center is represented by a distance of 1.649 inches on the fly wheel. It will be noted that in this case there is a lapse of three degrees between the exhaust closing and the inlet opening. The exhaust valve is kept open considerably longer than is usually the case, as it lags thirty-three degrees after the piston is started to go up on its compression stroke. The exhaust

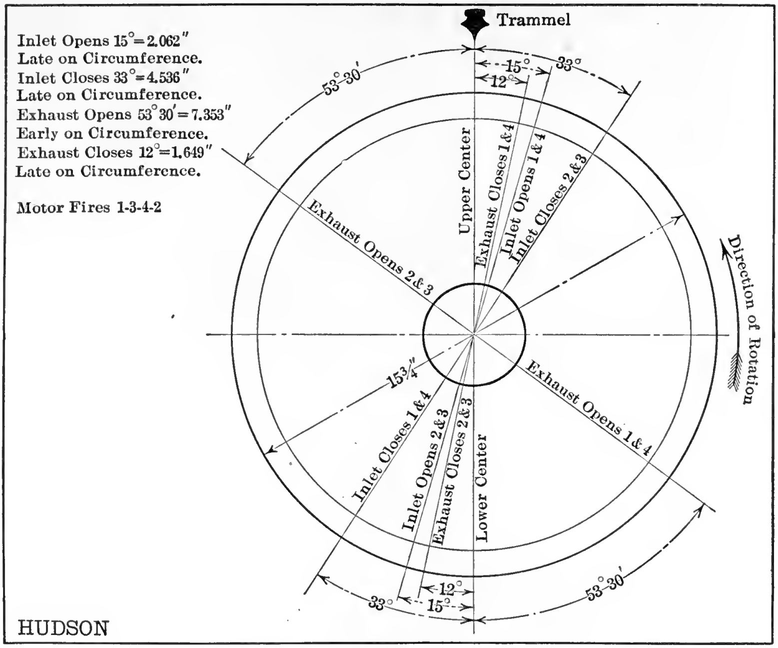


Fig. 94.—Diagram Showing Method of Marking Fly-wheel Circumference to Obtain Proper Timing of Typical Four-Cylinder Motor.

valve opens much earlier, i. e., it is given a greater lead than an analysis of common practice shows to be desirable. The exhaust valve is opened considerably longer than is usually the case, as the average lead given to exhaust is about forty degrees.

In timing a motor from the marks on the fly-wheel rim it is necessary to regulate the valves of but one cylinder at a time. Assuming that the fly wheel is revolving in the direction of the arrow and that the firing order of the cylinders is 1-3-4-2 the operation of timing would be carried on as follows: The fly wheel would be revolved until the line marked " Exhaust opens 1 and 4 " registered with the trammel on the motor bed. At this point the exhaust valve of either cylinder No. 1 or No. 4 should begin to open. This can be easily determined by noting which of these cylinders holds the compressed charge ready for ignition when the fly wheel is in the position shown in drawing. Assuming that the spark has occurred in cylinder No. 1, then when the fly wheel is turned from the position shown in the sketch to that in which the line marked " Exhaust opens 1 to 4 " coincides with the trammel point, the valve plunger under the exhaust valve of cylinder No. 1 should be adjusted in such a way that there is no clearance between it and the valve stem. Further movement of the wheel in the same direction should produce a lift of the exhaust valve. The fly wheel is turned about two hundred and forty-five degrees or about three-quarters of a revolution; then the line marked " Exhaust closes 1 and 4 " will register with the trammel point. At this period the valve plunger and the valve stem should separate and a certain amount of clearance obtained between them. The next cylinder to time would be No. 3. The fly wheel is rotated until mark " Exhaust opens 2 and 3 " comes in line with the trammel. At this point the exhaust valve of cylinder No. 3 should be just about opening. The closing is determined by rotating the fly wheel until the line " Exhaust closes 2 and 3 " comes under the trammel.

This operation is carried on with all the cylinders, it being well to remember that but one cylinder is working at a time and that a half revolution of the fly wheel corresponds to a full working stroke of all the cylinders, and that while one is exhausting, the others are respectively taking in a new charge, compressing and exploding. For instance, if cylinder No. 1 has just completed its power stroke the piston in cylinder No. 3 has reached the point where the gas may be ignited to advantage. The piston of cylinder No. 4, which is next to fire, is at the bottom of its stroke and will have inspired a charge, while cylinder No. 2, which is the last to fire, will have just finished expelling a charge of burned gas, and will be starting the intake stroke.

CHAPTER IV

Considering Pistons, Piston Rings, Connecting Rods, Crank Shafts, the Fly Wheel, and Engine Base Construction—Typical Two- and Four-Cycle Power Plants Described.

Constructional Details of Pistons.—The piston is one of the most important parts of the gasoline motor inasmuch as it is the reciprocating member that receives the impact of the explosion and which transforms the power obtained by the combustion of gas to mechanical motion by means of the connecting rod to which it is attached. The piston is one of the simplest elements of the motor, and it is one component which does not vary much in form in different types of motors. The piston is a cylindrical member provided with a series of grooves in which packing rings are placed on the outside and two bosses which serve to hold the wrist pin in its interior. It is usually made of cast iron, though in some motors where extreme lightness is desired, such as those used for aëronautic work, it may be made of steel. The use of the more resisting material enables the engineer to use lighter sections where it is important that the weight of this member be kept as low as possible consistent with strength.

A number of piston types are shown at Fig. 95. That at A has a round top and is provided with four split packing rings and two oil grooves. A piston of this type is generally employed in motors where the combustion chamber is large and where it is desired to obtain a higher degree of compression than would be possible with a flat top piston. This construction is also stronger because of the arched piston top. The most common form of piston is that shown at B, and it differs from that previously described only in that it has a flat top. The piston outlined in section at C is a type used on some of the sleeve-valve motors of the Knight pattern, and has a concave head instead of the convex form shown at A. The design shown at D in side and plan views is the conventional form employed in two-cycle engines. The deflector plate on the top of the cylinder is cast integral and is utilized to prevent the incoming fresh gases from flowing directly over the piston top and out of the exhaust port which is usually opposite the inlet opening. On those types of two-cycle engines where a two-diameter cylinder is employed, the piston shown at E is used. This is known as a " differential piston," and has an enlarged portion at its lower end which fits the pumping cylinder. The

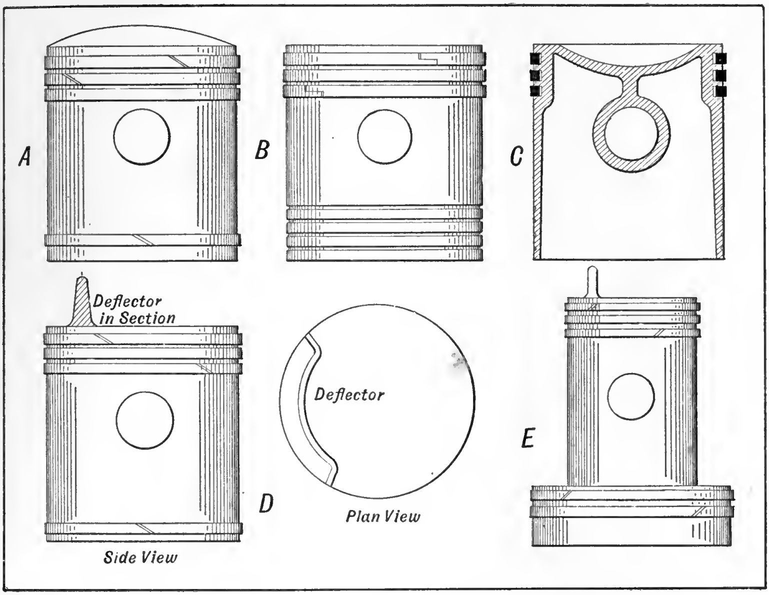


Fig. 95.—Forms of Pistons Commonly Employed in Gasoline Engines. A—Dome Head Piston with Three Packing Rings. B—Flat Top Form Almost Universally Used. C—Concave Piston Utilized in Knight Motors and Some Having Overhead Valves. D—Two-Cycle Engine Member with Deflector Plate Cast Integrally. E—Differential of Two-Diameter Piston Used in Some Engines Operating on Two-Cycle Principle.

usual form of deflector plate is provided at the top of the piston and one may consider it as two pistons in one.

One of the important conditions in piston design is the method of securing the wrist pin which is used to connect the piston to the upper end of the connecting rod. Various methods have been devised to keep the pin in place, the most common of these being shown at Fig.

96. The wrist pin should be retained by some positive means which is not liable to become loose under the vibratory stresses which obtain at this point. If the wrist pin was free to move it would work out of the bosses enough so that the end would bear against the cylinder wall. As it is usually made of steel, which is a harder material than cast iron used in cylinder construction, the rubbing action would tend to cut a groove in the cylinder wall which would make for loss of power because it would permit escape of gas. The wrist pin member is a simple cylindrical element that fits the bosses closely, and it may be either hollow or solid stock.

The method of retention shown at A is the simplest and consists of a set screw having a projecting portion passing into the wrist pin and holding it in place. The screw is kept from turning or loosening by means of a check nut. The method outlined at B is similar to that shown at A, except that the wrist pin is solid and the point of the set screw engages an annular groove turned in the pin for its reception. A very positive method is shown at C. Here the retention screws pass into the wrist pin and are then locked by a piece of steel wire which passes through suitable holes in the ends. The method outlined at D is sometimes employed, and it varies from that shown at C only in that the locking wire, which is made of spring steel, is passed through the heads of the locking screws. Some designers machine a large groove around the piston at such a point that when the wrist pin is put in place a large packing ring may be sprung in the groove and hold the wrist pin in place.

The system shown at F is not so widely used as the simpler methods, because it is more costly and does not offer any greater security when the parts are new than the simple lock shown at A. In this a hollow wrist pin is used, having a tapered thread cut at each end. The wrist pin is slotted at three or four points, for a distance equal to the length of the boss, and when taper expansion plugs are screwed in place the ends of the wrist pin are expanded against the bosses. This method has the advantage of providing a certain degree of adjustment if the wrist pin should loosen up after it had been in use for some time. The taper plugs would be screwed in deeper and the ends of the wrist pin expanded proportionately to take up the loss motion. The method shown at G is an ingenious one. One of the piston bosses is provided

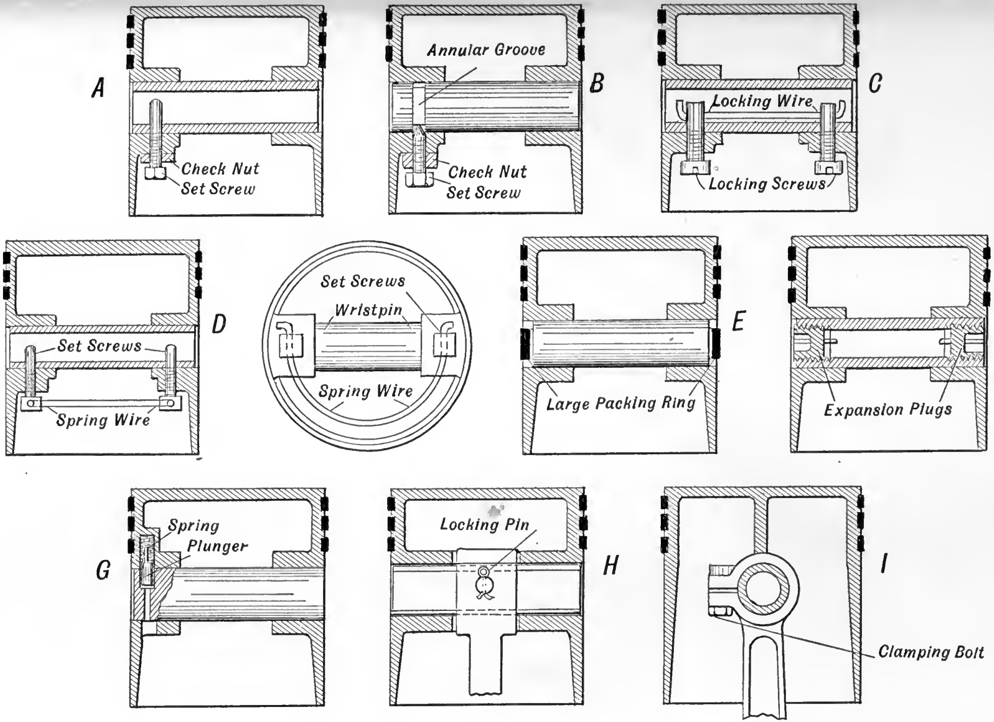


Fig. 96.—Typical Methods of Piston Pin Retention Generally Used in Engines of American Design. A—Single Set Screw and Lock Nut. B—Set Screw and Check Nut Fitting Groove in Wrist Pin. C, D—Two Locking Screws Passing Into Interior of Hollow Wrist Pin. E—Split Ring Holds Pin in Place. F—Use of Taper Expanding Plugs Outlined. G—Spring Pressed Plunger Type. H—Piston Pin Pinned to Connection Rod. I—Wrist Pin Clamped in Connecting Rod Small End by Bolt.

with a projection which is drilled out to receive a plunger. The wrist pin is provided with a hole of sufficient size to receive the plunger, which is kept in place by means of a spring in back of it. This makes a very positive lock and one that can be easily loosened when it is desired to remove the wrist pin. To unlock, a piece of fine rod is thrust into the hole at the bottom of the boss and pushes the plunger back against the spring until the wrist pin can be pushed out of the piston.

Some engineers think it advisable to oscillate the wrist pin in the piston bosses, instead of in the connecting rod small end. It is argued that this construction gives more bearing surface at the wrist pin and also provides for more strength because of the longer bosses that can be used. When this system is followed the piston pin is held in place by locking it to the connecting rod by some means. At H the simplest method is outlined. This consisted of driving a taper pin through both rod and wrist pin and then preventing it from backing out by putting a split cotter through the small end of the tapered locking pin. Another method, which is depicted at I, consists of clamping the wrist pin by means of a suitable bolt which brings the slit connecting rod end together as shown.

Piston Ring Construction.—As all pistons must be free to move up and down in the cylinder with minimum friction, they must be less in diameter than the bore of the cylinder. The amount of freedom or clearance provided varies with the construction of the engine, but it is usual to provide from .005 to .010 of an inch to compensate for the expansion of the piston due to heat and also to leave sufficient clearance for the introduction of lubricant between the working surfaces. Obviously, if the piston were not provided with packing rings, this amount of clearance would enable a portion of the gases evolved when the charge is exploded to escape by it into the engine crank case. The packing members or piston rings, as they are called, are split rings of cast iron, which are sprung into suitable grooves machined on the exterior of the piston, three or four of these being the usual number supplied. These have sufficient elasticity so that they bear tightly against the cylinder wall and thus make a gas-tight joint. Owing to the limited amount of surface in contact with the cylinder wall and the elasticity of the split rings the amount of friction resulting from the contact of properly fitted rings and the cylinder is not of enough moment to cause any damage and piston is free to slide up and down in the cylinder bore.

These rings are made in two forms, as outlined at Fig. 97. The design shown at A is termed a "concentric ring," because the inner circle is concentric with the outer one and the ring is of uniform

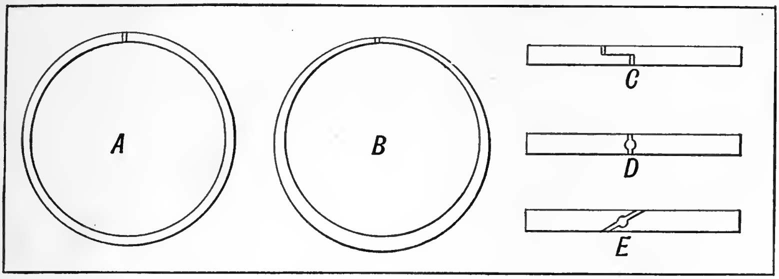


Fig. 97.—Types of Piston Rings and Ring Joints. A—Concentric Ring. B—Eccentrically Machined Form. C—Lap Joint Ring. D—Butt Joint, Seldom Used. E—Diagonal Cut Member, a Popular Form.

thickness at all points. The ring shown at B is called an "eccentric ring," and it is thicker at one part than the other. It has theoretical advantages in that it will make a tighter joint than the other form, as it is claimed its expansion due to heat is more uniform. The piston rings must be split in order that they may be sprung in place in the grooves, and also to insure that they will have sufficient elasticity to take the form of the cylinder at the different points in their travel. If the cylinder bore varies by small amounts the rings will spring out at the points where the bore is larger than standard, and spring in at those portions where it is smaller than standard.

It is important that the joint should be as nearly gas-tight as possible, because if it were not a portion of the gases would escape through the slots in the piston rings. The joint shown at C is termed a "lap joint," because the ends of the ring are cut in such a manner that they overlap. This is the approved joint. The butt joint shown at D is seldom used and is a very poor form, the only advantage being its cheapness. The diagonal cut shown at E is a compromise between the very good form shown at C and the poor joint depicted at D. It is also widely used, though most constructors prefer the lap joint, because it does not permit the leakage of gas as much as the other two types.

The illustration at Fig. 98 shows a typical flat top piston, provided with diagonal cut concentric packing rings. One of these members is

Fig. 98.—Showing Flat-Top Piston Provided with Four Concentric Rings, One of the Packing Members and the Wrist Pin with its Bushing.

shown on top of the piston and the wrist pin and the bushing which fits it and which is forced into the small end of the connecting rod are placed at one side. In some cases the piston rings are pinned in place in their grooves so that they cannot move around until they are all in such a position that the slots will come in line. In others, it is believed that they are left free to turn that they will wear in place and conform to the bore of the cylinder better than if they are kept from turning. When the rings are pinned they usually have the diagonal cut, while those that are left free are usually provided with the lap joint.

Connecting Rod Forms.—The connecting rod is the simple member that joins the piston to the crank shaft and which transmits the

Fig. 99.—Typical Connecting Rod and its Wrist Pin. Lower Bearing Cap Held by Four Bolts. White Metal Boxes in Cast Bronze Rod.

power imparted to the piston by the explosion so that it may be usefully applied. It transforms the reciprocating movement of the piston to a rotary motion at the crank shaft. A typical connecting rod and its wrist pin are shown at Fig. 99. It will be seen that it has two bearings, one at either end. The small end is bored out to receive the wrist pin which joins it to the piston, while the large end has a hole of sufficient size to go on the crank pin. The connecting rod is usually a steel forging, though it is sometimes made a steel or high tensile strength bronze casting. In all cases it is desirable to have softer metals than the crank shaft and wrist pin at the bearing point, and for this reason the connecting rod is usually provided with bushings of anti-friction or white metal at the lower end, and bronze at the upper. The upper end of the connecting rod may be one piece, because the wrist pin can be introduced after it is in place between the bosses of the piston. The lower bearing must be made in two parts in most cases, because the crank shaft cannot be passed through the bearing owing to its irregular form.

Some of the various designs of connecting rods that have been used are shown at Fig. 100. That at A is a simple form often employed in single-cylinder motors, having built-up crank shafts. Both ends of the connecting rod are bushed with a one-piece bearing, as it can be assembled in place before the crank-shaft assembly is built up. A built-up crank shaft such as this type of connecting rod would be used with is shown at Fig. 106. The pattern shown at B is one that has been used to some extent on heavy work, and is known as the "marine type." It is made in three pieces, the main portion being a steel forging having a flanged lower end to which the bronze boxes are secured by bolts. The modified marine type depicted at C is the form that has received the widest application in automobile construction. It consists of two pieces, the main member being a steel drop forging having the wrist-pin bearing and the upper crank-pin bearing formed integral, while the lower crank-pin bearing member is a separate forging secured to the connecting rod by bolts. In this construction bushings of anti-friction metal are used at the lower end, and a bronze bushing is forced into the upper- or wrist-pin end. The rod shown at D has also been widely used. It is similar in construction to the form shown at C, except that the upper end is split in order to permit of a degree of adjustment of the wrist-pin bushing, and the lower bearing cap is a hinged member which is retained by one bolt instead of two. When it is desired to assemble it on the crank shaft the lower cap is swung to one side and brought back into place when the connecting rod has been properly located. Sometimes the lower bearing member is split diagonally instead of horizontally, such a construction being outlined at E.

In a number of instances, instead of plain bushed bearings anti-friction forms using ball or rollers have been used at the lower end. A ball-bearing connecting rod is shown at F. The big end may be made in one piece, because if it is possible to get the ball bearing on the crank pins it will be easy to put the connecting rod in place. Ball bearings are not used very often on connecting rod big ends because of difficulty of installation, though when applied properly they give satisfactory service and reduce friction to a minimum. One of the advantages of the ball bearing is that it requires no adjustment, whereas the plain bushings depicted in the other con-

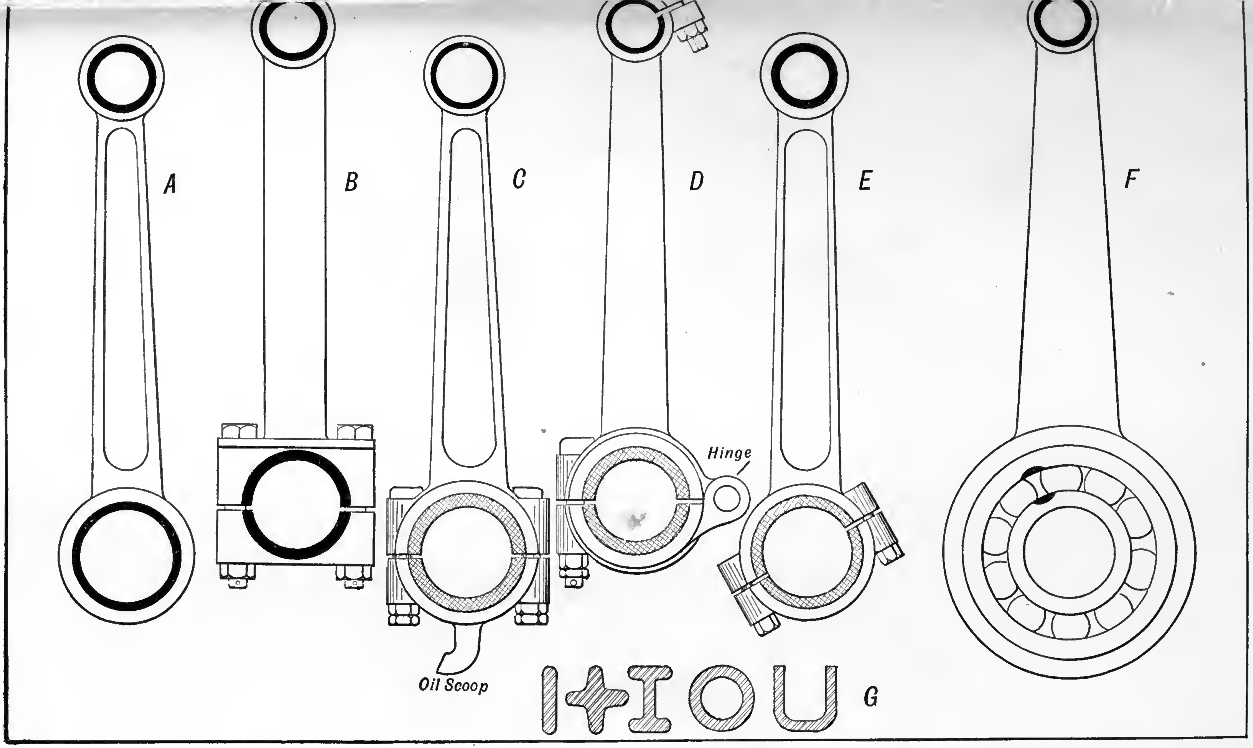


Fig. 100.—Connecting-Rod Types Summarized. A—Simple Connecting Rod Made in One Piece, Usually Fitted in Small Single-Cylinder Engines Having Built-Up Crank Shafts. B—Marine Type, a Popular Form on Heavy Engines. C—Conventional Automobile Type, a Modified Marine Form. D—Type Having Hinged Lower Cap and Split Wrist-Pin Bushing. E—Connecting Rod Having Diagonally Divided Big End. F—Ball-Bearing Rod. G—Sections Showing Structural Shapes Commonly Employed in Connecting-Rod Construction.

necting rods must be taken up from time to time to compensate for wear.

This can be done in forms shown at B, C, D, and E by bringing the lower bearing caps closer to the upper one and scraping out the

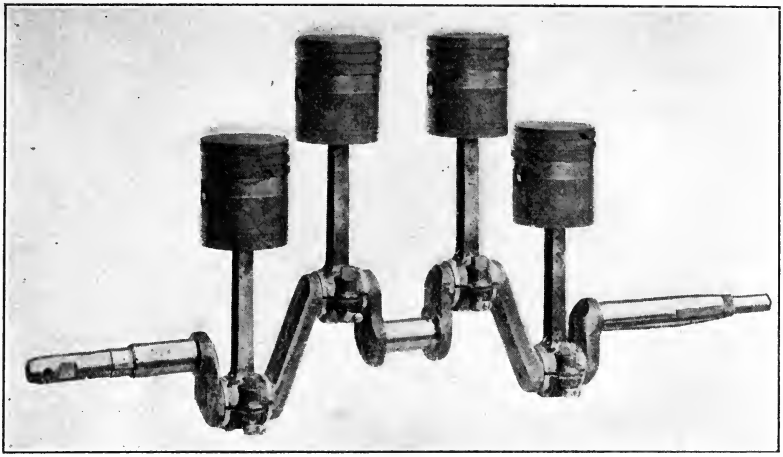


Fig. 101.—Crank Shaft, Piston and Connecting Rod Assembly Used in Reo Motors.

brasses to fit the shaft. A number of liners or shims of thin brass or copper stock varying from .002 inch to .005 inch are sometimes interposed between the halves of the bearings when it is first fitted to the crank pin. As the brasses wear the shims may be removed and the portions of the bearings brought close enough together to take up any lost motion that may exist.

The various structural shapes in which connecting rods are formed are shown in section at G. Of these the I section is most common, because it is strong and a very easy shape to form by the drop-forging process. Where extreme lightness is desired, as in small high-speed motors used for cycle propulsion, the section shown at the extreme left is often used. If the rod is a cast member the cross, hollow cylinder, or U sections are sometimes used. If the sections shown at the right are employed, advantage is often taken of the opportunity for passing lubricant through the center of the hollow round section on vertical motors or at the bottom of the U section, which would be used on a horizontal cylinder power plant.

Cam-Shaft Forms.—Piston and connecting rod types having been described, the next component of importance to receive attention should be the crank shaft. These vary in form according to the designs of the motor and number of cylinders employed. A typical crank shaft, piston, and connecting rod assembly which forms part of the Reo motor is shown at Fig. 101, and the parts are so clearly shown that no description is necessary.

Before going extensively into the subject of crank-shaft construction it will be well to consider cam-shaft design, which is properly a part of the valve system and which should be considered in connection

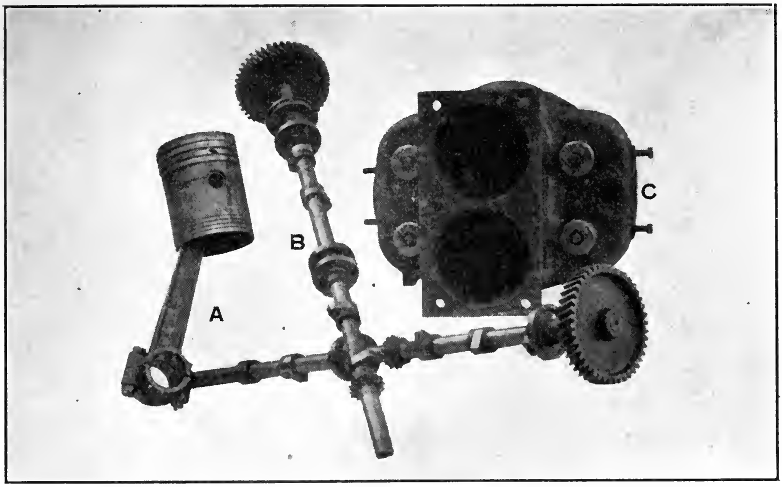


Fig. 102.—Some of the Components of Corbin " 40 " Motor. A—Piston and Connecting Rod Assembly. B—Inlet and Exhaust Cam Shafts. C—Twin-Cylinder Casting.

with the other elements which have to do directly with cylinder construction. Cam shafts are usually simple members carried at the base of the cylinder in the engine case by suitable bearings and having the cams employed to lift the valves attached at intervals. A typical cam-shaft design is shown at Fig. 102 in connection with one of the twin-cylinder castings and the piston and connecting rod assembly of the

Corbin "40" motor. Two main methods of cam-shaft construction are followed—that in which the cams are separate members, keyed and pinned to the shaft, and the other where the cams are formed integral.

The cam shafts shown at Fig. 102 are of the former type, as the cams are machined separately and held in place by means of keys and

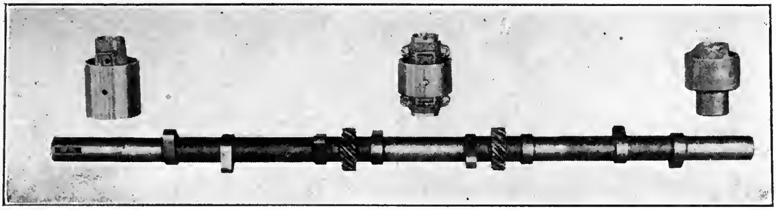


Fig. 103.—Typical Cam Shaft with Valve Lifting Cams and Gears to Operate Auxiliary Devices Forged Integrally.

taper pins. The small gears used to drive some of the accessory mechanism, such as the oil pump, timer, etc., are also separately formed and pinned to the cam shaft. At Fig. 103 the other method of cam-shaft construction is outlined. In this case not only the cams but also the gears used in driving the auxiliary shafts are forged integral. This is a more expensive construction than that shown at Fig. 102, because of the high initial cost of forging dies as well as the greater expense of machining. It has the advantage over the other form in which the cams are keyed in place in that it is stronger, and as the cams are a part of the shaft they can never become loose, as might be possible where they are separately formed and assembled on a simple shaft. As an example of an auxiliary shaft carried at the side of the motor and driven from the cam shaft the assembly at Fig. 104 is given. This is driven from one of the small gears shown at Fig. 103 and carries the ignition timer at the upper end and drives the oil pump through a spring coupling at its lower end.

Crank-shaft Types Outlined.—The importance of the crank shaft has been previously considered, and some of its forms have been shown in views of the motors presented in earlier portions of this work. The crank shaft is one of the parts subjected to the greatest strain and extreme care is needed in its construction and design, because prac-

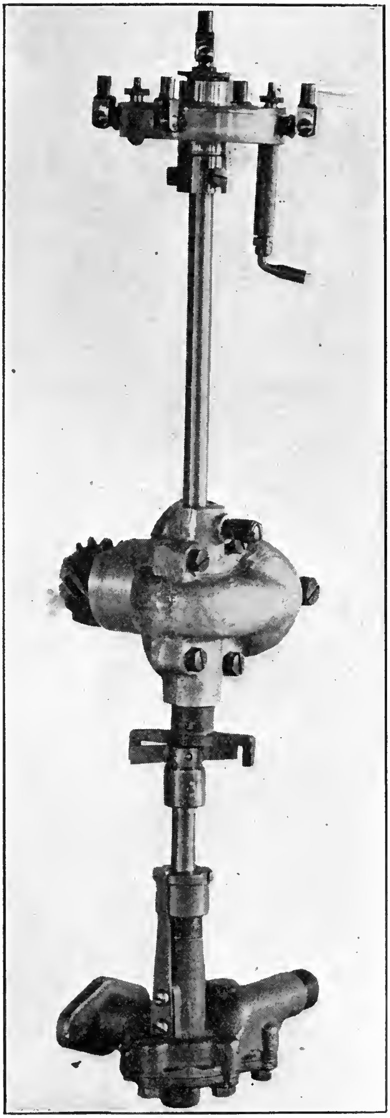


Fig. 104.—Auxiliary Shaft Used in Connection with Cam Shaft Driven from a Spiral Gear Turns Timer and Oil Pump.

tically the entire duty of transmitting the power generated by the motor to the gearset devolves upon it. Crank shafts are usually made of high tensile strength steel of special composition. They may be made in four ways, the most common being from a drop or machine forging which is formed approximately to the shape of the finished shaft and in rare instances they may be steel castings. Sometimes they are made from machine forgings, where considerably more machine work is necessary than would be the case where the shaft is formed between dies. Some engineers favor blocking the shaft out of a solid slab of metal and then machining this rough blank to form. In some single-cylinder motors of the enclosed fly-wheel type the crank shaft and fly wheel are built up as a unit.

The form of the shaft depends on the number of cylinders and the form has material influence on the method of construction. For instance, a one-, two- or four-cylinder crank shaft could be made by either of the methods outlined. On the other hand, a three- or six-cylinder shaft is best made by the machine forging process, because if drop forged or cut from the blank it will have to be heated and the crank throws bent around so that the pins will lie in three planes one hundred and twenty degrees apart, while the other types described need no further attention, as the crank pins lie in planes one hundred

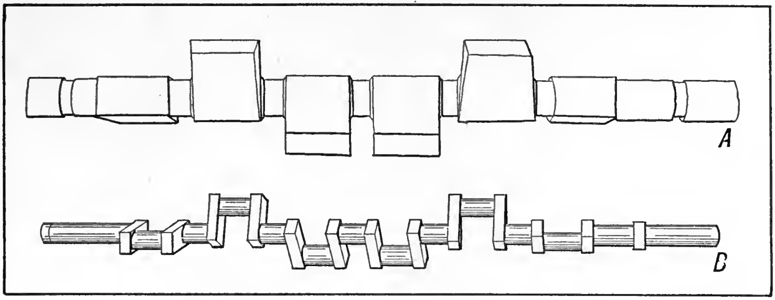


Fig. 105.—Showing Method of Making Crank Shaft. A—The Rough Steel Forging Before Machining. B—The Finished Six-Throw, Seven-Bearing Crank Shaft.

and eighty degrees apart. This can be better understood by referring to Fig. 105, which shows a six-cylinder shaft in the rough and finished stages. At A the appearance of the machine forging before any of the material is removed is shown, while at B the appearance of the finished crank shaft is clearly depicted. The built-up crank shaft is seldom used on multiple-cylinder motors, except in some cases where the crank shafts revolve on ball bearings and the connecting rods are provided with this form as well.

A typical single-cylinder high-speed motor is shown at Fig. 106, this being the De Dion-Bouton, a power plant which has been quite popular in France in the past for "voiturette" or small car use. In this design the fly wheels are enclosed in the crank case and the crank shaft is a built-up construction formed of five pieces. The two halves of the crank shaft fit into taper holes in the fly wheels and are held securely in place by means of keys and clamping nuts. The crank pin is similarly retained. Brief study of the illustration will show this method of construction very clearly. It should be stated that this is seldom used on automobile motors but that it is very common construction in motorcycle power plants.

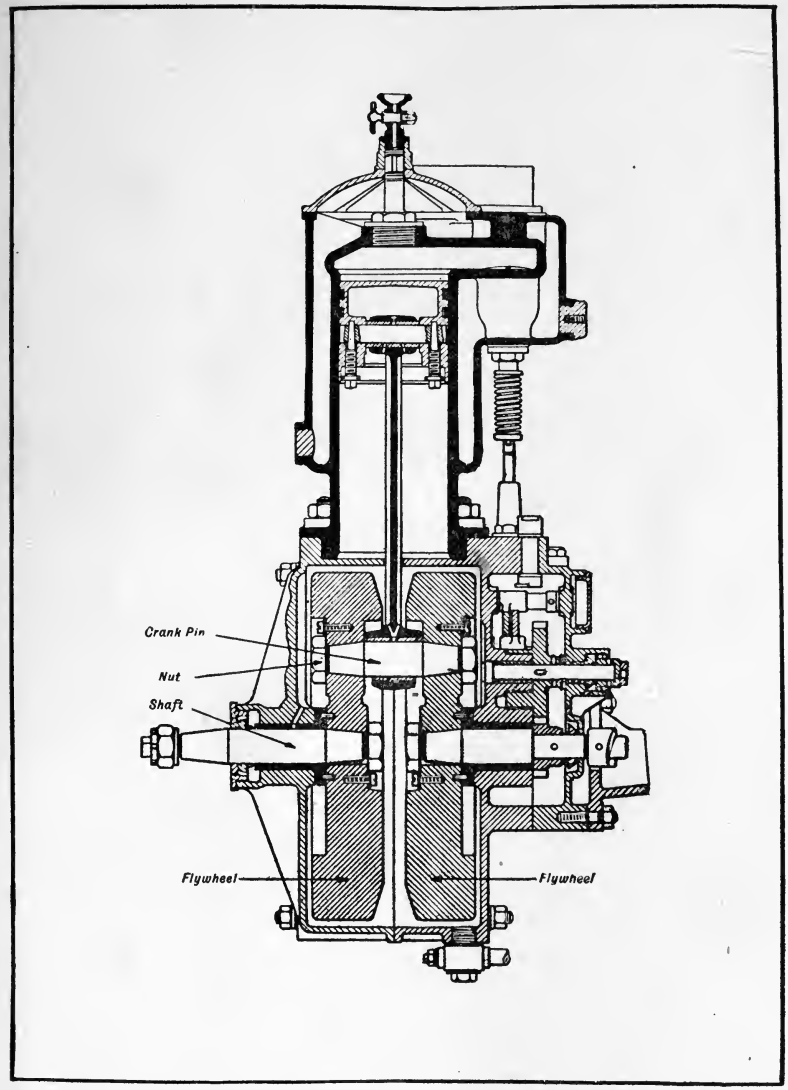


Fig. 106.—Defining Built-up Crank-shaft Construction Sometimes Used in Small Motors.

Crank-shaft form will vary with a number of cylinders and it is possible to use a number of different arrangements of crank pins and bearings for the same number of cylinders. The simplest form of

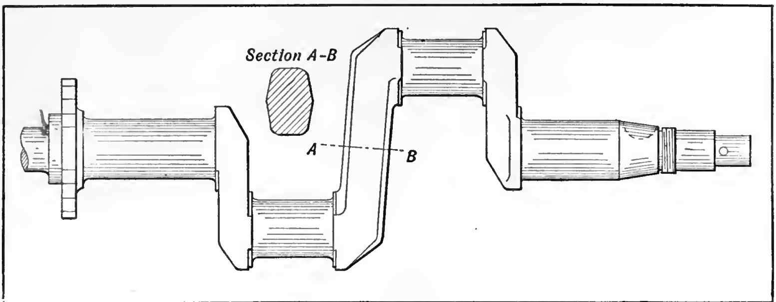


Fig. 107.—Showing Form of Crank Shaft for Twin-Cylinder Opposed Power Plant.

crank shaft is that used on a one-cylinder motor, as it would consist of but one crank pin, two webs, and the crank shaft. As the number

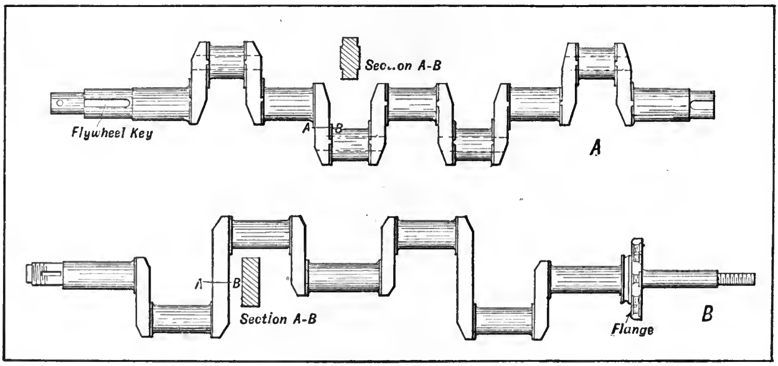


Fig. 108.—Two Forms of Four-Cylinder Crank Shaft. A—Five-Bearing Type with Fly-wheel Fastening Key at Front End. B—Three-Bearing Type with Flange for Securing Fly-wheel Formed Integral.

of cylinders increase, as a general rule more crank pins are used. The crank shaft that would be used on a two-cylinder opposed motor is shown at Fig. 107. This has two throws and the crank pins are spaced 180 degrees apart. The bearings are exceptionally long and a flange is forged integral at the rear end for fly-wheel retention. Four-cylinder crank shafts may have two, three or five main bearings and three or four crank pins. In some forms of two-bearing crank shafts, such as used when four cylinders are cast in a block, or unit casting, two of the pistons are attached to one common crank pin, so that in reality the crank shaft has but three crank pins. Such a form is shown at Fig. 112, which depicts a four-cylinder two-bearing crank shaft used on Chalmers' motors.

When the cylinders are cast individually five-bearing crank shafts are the rule. One of these, which is used on Maxwell engines, is shown

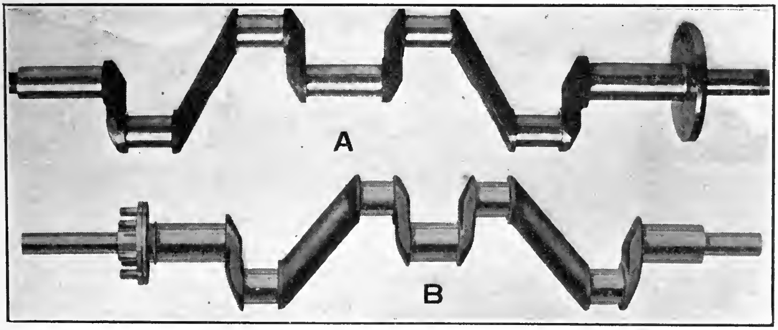


Fig. 109.—Representative Three-Bearing Crank Shafts. A—For Use with Cylinders Cast in Pairs. B—Used with Individually Cast Cylinders. Note Round Section Portions Connecting Ends to Center Crank Throws.

at Fig. 108, A. The three-bearing type shown at Fig. 108, B, is used when the cylinders are cast in pairs. Two other three-bearing shafts used in four-cylinder motors are shown at Fig. 109. That at A forms part of the E. M. F. engine, which has the cylinders cast in pairs, while the three-bearing four-throw type, shown at B, is used in the Rambler four-cylinder engine, which has individually cast cylinders. Six-cylinder crank shafts usually have four or seven main bearings depending upon the disposition of the crank pins and arrangement of cylinders. At Fig. 110 the bottom view of a Premier six-cylinder engine with bottom half of crank case removed is given. This illustrates clearly the arrangement of crank pins and main bearings when the crank shaft is supported on four journals. The crank shaft shown at Fig. 105, B, is a six-cylinder seven-bearing type.

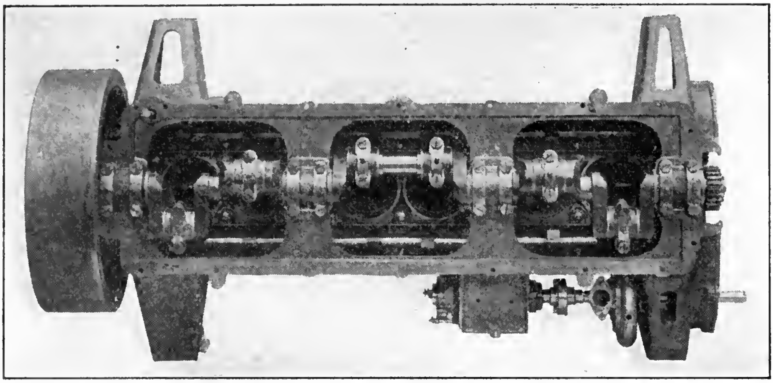


Fig. 110.—Bottom View of Premier Engine Showing Four-Bearing, Six-Cylinder Crank Shaft with Connecting Rods in Place.

Ball-Bearing Crank Shafts.—While crank shafts are usually supported in plain journals there seems to be a growing tendency of late to use anti-friction bearings of the ball type for their support. This is

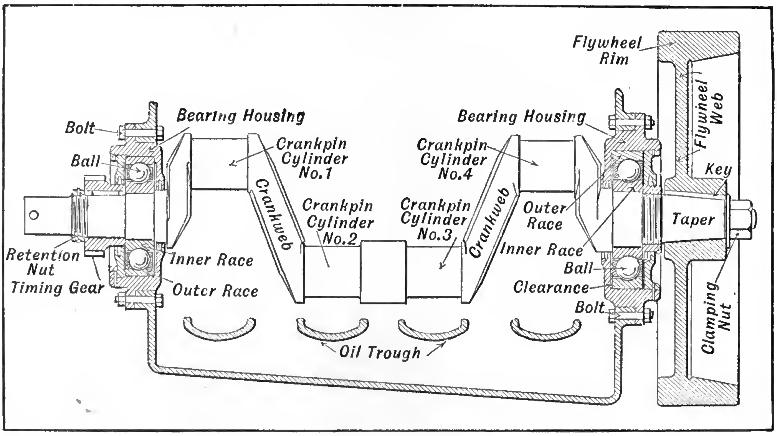


Fig. 111.—Design of Four-Cylinder Crank Shaft Mounted on Two Annular Ball Bearings. Note Method of Fly-wheel Retention by Key and Taper and Bearing Housing.

especially noticeable on block motors where but two main bearings are utilized. When ball bearings are selected with proper relation to the load which obtains they will give very satisfactory service. They permit the crank shaft to turn with minimum friction, and if properly selected will never need adjustment. The drawing at Fig. 111 shows the usual method of mounting a four-cylinder crank shaft on two annular ball bearings. The front end is supported by a bearing which is clamped in such a manner that it will take a certain amount of load in a direction parallel to the axis of the shaft, while the rear end is so supported that the outer race of the bearing has a certain amount

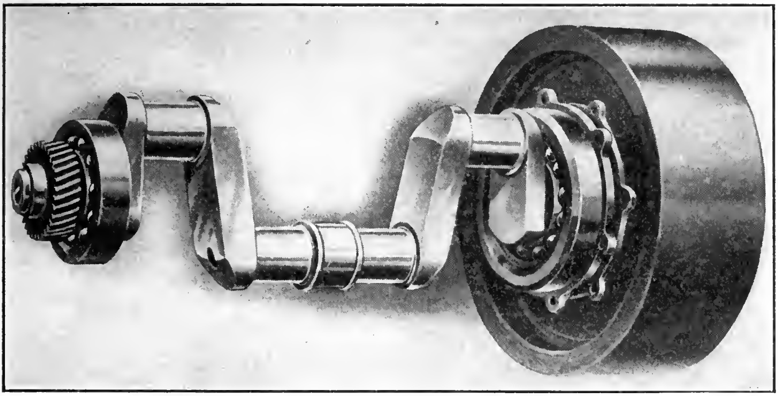


Fig. 112.—Four-Throw, Two-Bearing Chalmers Crank Shaft Mounted on Anti-Friction Journals of the Ball-Bearing Type.

of axial freedom or "float." The inner race or cone of each bearing is firmly clamped against shoulders on the crank shaft. At the front end of the crank-shaft timing gear and a suitable check nut are used, while at the back end the bearing is clamped by a threaded retention member between the fly wheel and a shoulder on the crank shaft. The fly wheel is held in place by a taper and key retention. The ball bearings are carried in a housing of bronze or malleable iron, which in turn are held in the crank case by bolts. The two-bearing crank shaft shown at Fig. 112 is that used in Chalmers' motors, while a three-bearing crank shaft supported on anti-friction members of the ball type which has been used successfully on Lozier cars is shown at Fig.

113. Figs. 111 and 112 show designs of two-bearing, four-cylinder crank shafts, such as used in block motors very clearly, while the form depicted at Fig. 113 forms part of a motor having the cylinders cast in pairs.

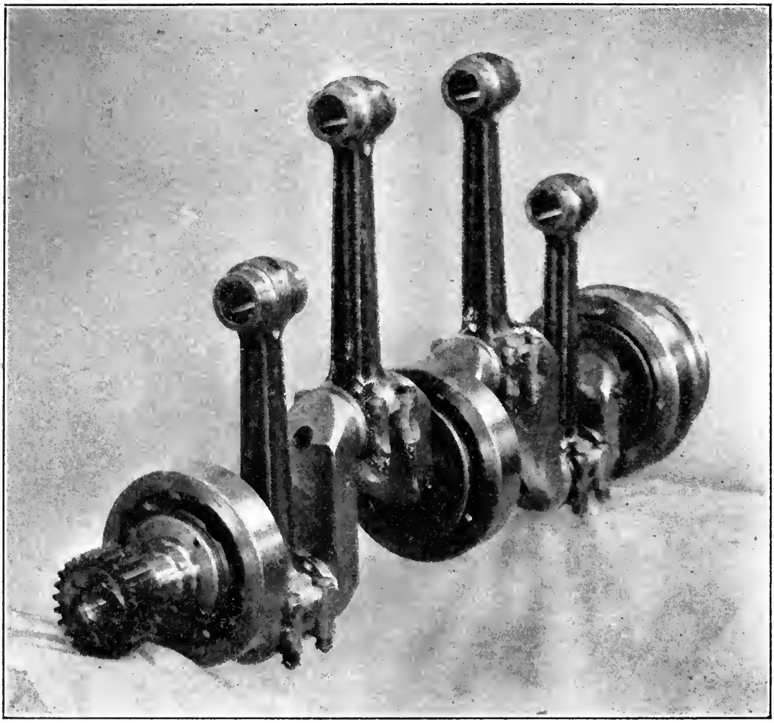


Fig. 113.—Four-Throw, Three-Bearing Lozier Crank Shaft and Connecting Rod Assembly Mounted on Three Large Annular Ball Bearings. Note Connecting Rod Design and the Use of Plain Bearings at Both Wrist-pin and Crank-pin Ends.

Fly-wheel Construction and Retention.—In explaining the principle of operation of the internal combustion engine it was made clear that there were four strokes of the piston necessary to complete the cycle of operation in any one cylinder, and of these but one was a useful or power stroke. The gasoline engine would not be a practical power producer, especially if made in one- and two-cylinder patterns, without some means of equalizing the uneven power generation. Considering first the single-cylinder motor, we find that we have but one explosion every four strokes, and as this represents two revolutions of the crank shaft it will be evident that it is necessary to store up energy by some means in order to carry the crank shaft through the idle strokes. This is accomplished by supplying a heavy wheel which is secured in a positive manner to the crank shaft and which turns with it. When the explosion drives the piston down considerable energy is stored in the fly-wheel rim and it will continue to revolve after the impulse given it has diminished in value to a considerable extent. In fact there is enough energy stored in the fly wheel of proper weight to carry the piston through all the idle strokes and to equalize the torque produced. This insures an even turning moment and makes for uniform application of power to the mechanism.

The fly-wheel weight is dictated largely by the number of cylinders employed, it being a general rule that the motors having the least number of cylinders require the heaviest fly wheels. This means that a single-cylinder motor will need a heavier equalizing member than one having a greater number of cylinders and a more even turning moment at the crank shaft. As an example of how the number of cylinders directly affects fly-wheel weight, one may say that if a single-cylinder engine of given power required a fly wheel of two hundred pounds weight to equalize the power effect, a double-cylinder engine would need one of about one hundred and sixty pounds, a four-cylinder engine would use one weighing but one hundred pounds, while a six-cylinder motor would furnish a uniform torque with a fly-wheel member weighing no more than sixty pounds. Fly-wheel weight is determined by many conditions, some of the important ones being bore of the cylinder, speed of crank-shaft rotation, degree of compression, and mode of transmission. It is common practice to provide a fly wheel somewhat heavier than the actual requirements on multi-cylinder motors of large bore so that these may be more easily started by a person of average strength.

Fly-wheel types vary from simple spoked members resembling a belt pulley with a heavy rim to others having fan-shaped spokes and light rims. Where a sliding gear transmission is used it is customary to make one of the clutch members integral with the fly wheel. For instance, at Fig. 114 a typical fan-blade fly wheel adapted for use with a cone clutch is shown. This has a central web member which forms

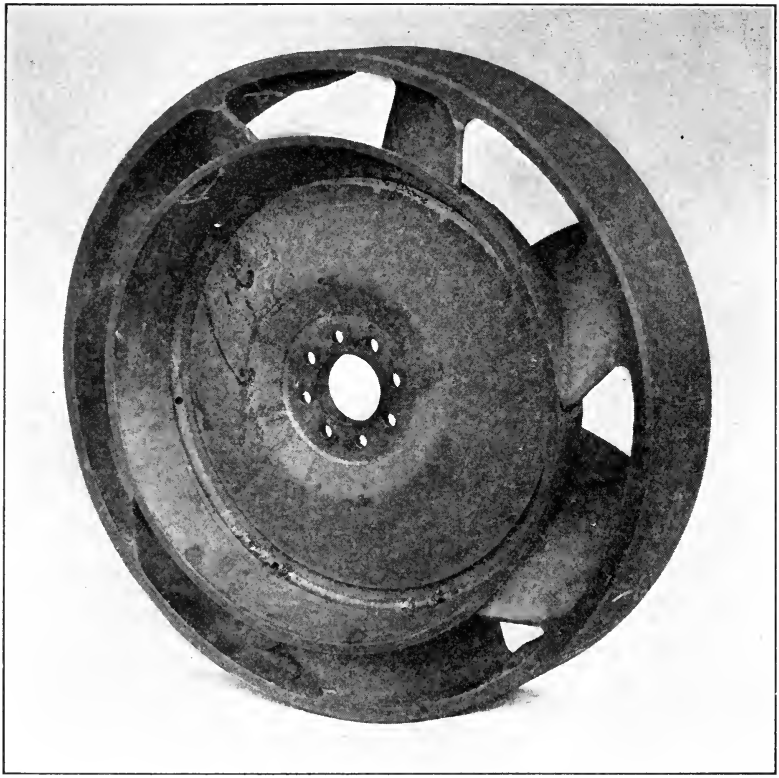


Fig. 114.—Typical Fly Wheel Showing Female Member of Cone Clutch and Fan-Blade Spokes. Rim is Light Because of Large Diameter.

the back of a saucer-shaped casting which serves as a female member of the cone clutch. From the periphery of this, the spokes radiate to the rim. As the fly wheel is of comparatively large diameter the rim is lighter than would be necessary if the weight were concentrated nearer the center of the crank shaft. At Fig. 115 the rear view of a power plant is given showing a simple type of fan-blade fly wheel, which is secured to the crank shaft by means of four bolts. As this member is designed for use with a type of gearset with the clutches

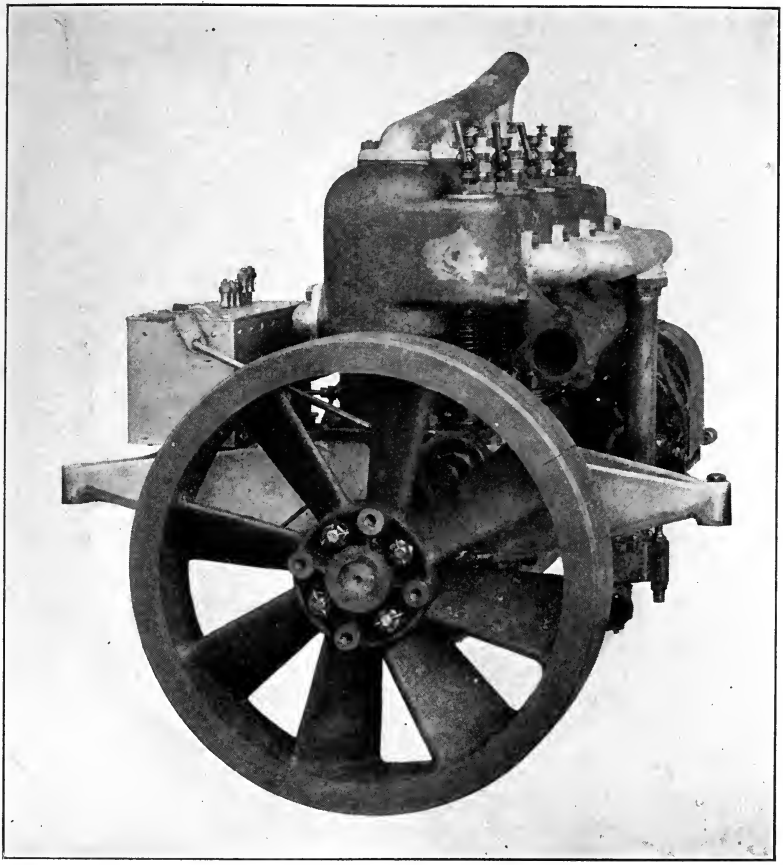


Fig. 115.—Rear View of Overland Power Plant Showing Fan-Blade Spoke Fly-wheel Construction.

incorporated, it is not necessary to provide for part of the clutch in the fly-wheel casting.

The diameter of a fly wheel must be held to certain limits and this restricts the useful weight one can put at the rim. If the fly wheel is placed low in the car it cannot be of large diameter, because one must have at least twelve or fourteen inches clearance between the bottom of the fly wheel and the roadway. Then again, the factor of centrifugal force must be taken into account, as when a fly wheel revolves there is a tendency for the particles of which it is composed to fly out in a direction tangential to the circle of rotation, and this force tends to rupture the rim. If steel is used instead of cast iron, the fly wheel may be of larger diameter, because the stronger material has greater resistance to this rupturing stress, but these wheels are not easy to make because in ordinary motor car sizes they must be steel castings and are thus quite costly. For a cast-iron fly wheel a safe value for speed of rotation of a point on the rim is about a mile a minute. It will be seen that the diameter must be such that the fly wheel may be run at maximum speeds without danger of bursting.

A fly wheel having a solid web joining the hub and rim is considerably stronger than one of the spoke type. The object of providing spokes shaped like fan blades is to take advantage of a suction effect produced to draw air from the motor compartment and exhaust it under the car. In some cars the draft created by the fly wheel is depended upon to supply the air needed for cooling the engine, either by applying it directly to the cylinders or by pulling it through the interstices of a water-cooling radiator. It is considered desirable to concentrate as much of the weight of the fly wheel at the rim as possible, because the further away from center the weight is carried the more effective the fly wheel is as a reservoir of energy and equalizer of torque.

Positive Fly-wheel Retention Important.—Methods of fly-wheel retention vary to some extent, and the main point observed by most designers is to use as secure a method of attaching it to the crank shaft as possible. The common systems of retention employed are shown at Fig. 116. The simplest of these is depicted at A. This consists merely of forcing the shaft into the fly-wheel hub and keeping the fly wheel from turning on the shaft by a substantial key which fits keyways machined in both shaft and fly-wheel hub. This method was formerly used to a greater extent than it is at present, but its use has been practically abandoned, except on marine engines, because the means of fastening was not reliable. The intermittent application of power to the fly wheel meant that its speed of rotation was accelerated at a certain point of the crank-shaft travel corresponding to the power stroke and checked at the other, or idle strokes. This produced stresses which tended to loosen the fly wheel on the key, and as soon as the retaining member was slightly loose a very disagreeable knocking

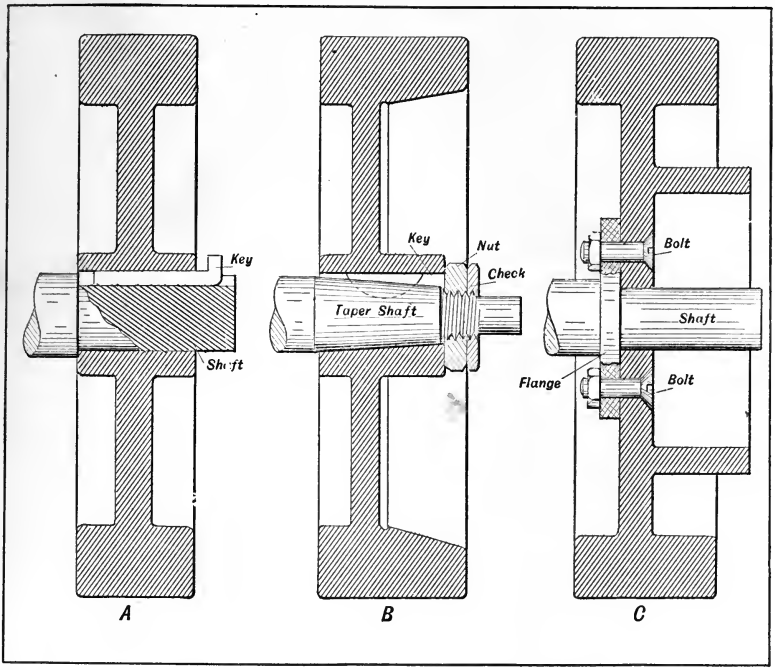


Fig. 116.—Outlining Methods of Fly-wheel Retention Commonly Used. A—By Gib Key. B—By Woodruff Key, Taper and Clamp Nut. C—By Bolting to Flange Forged Integrally with Crank Shaft.

sound was produced by the hammering action of the loose fly wheel on its retaining key.

At B a system often employed on types of crank shafts where it is not practical to use the preferred method shown at C is outlined. For instance, when ball bearings are applied it is necessary that they be put on the shaft from each end and if a flange was formed integral it would not be possible to use ball bearings except of very large bore.

Then again, some engineers using alloy steel for crank-shaft construction machine it from a slab of that material, and in order to reduce cost of manufacture no attempt is made to form the flange integral with the shaft. In this the end of the shaft designed to support the

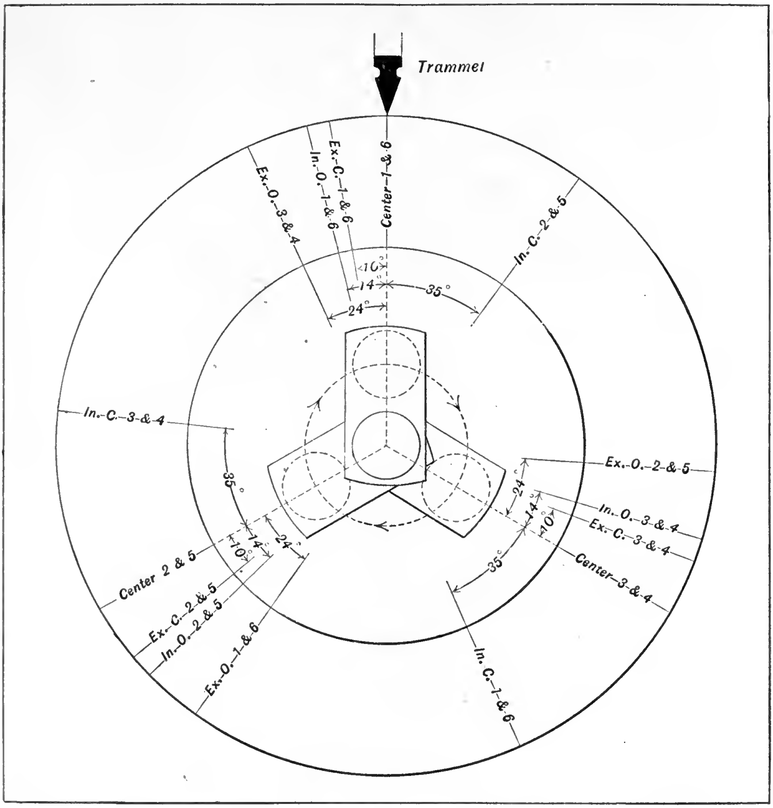


Fig. 117.—Showing Method of Marking Rim of Six-Cylinder Fly Wheel for Guiding Repairman or Motorist to Retain Correct Valve Timing.

fly wheel is tapered, as is also the fly-wheel hub. In addition to the taper a Woodruff key is usually let into the shaft and keyway cut into the fly-wheel hub to receive it. When the fly wheel is forced on the taper by the clamping nut it is firmly retained by the key, and at the same time the wedging effect of the taper and the pressure of the clamping nut prevents the fly wheel from loosening. The fly wheel at B has a portion of the rim machined on a taper, so it can receive the male member of a cone-type clutch.

The fly wheel shown at C is held by the preferred method. In forging the crank shaft a flange is formed integral and the fly wheel is secured to this flange by means of suitable retaining screws or bolts. If these are properly fitted it is practically impossible for the fly wheel to loosen on the flange, and as the flange is a part of the shaft it is obviously impossible for it to become separated therefrom. The fly wheel shown at C is provided with a casing formed integral which is designed to receive a clutch of the multiple-disk pattern.

The writer has previously explained the action of the valve mechanism and diagrams have been presented to show the sequence of the strokes. Most manufacturers mark the fly wheel with the various points at which valves should open or close. This not only facilitates work at the plant of the producer, but it insures that the timing will be restored to the proper point in event of taking the engine down for repair at some garage or machine shop. The various points are laid out on the fly-wheel periphery by means of steel stamps or letters, which may be easily interpreted. The position of these lines is determined by the peculiarities of that specific engine, and will vary in the different designs. The layout is always made with reference to some fixed point on the motor bed, this usually being a small metal pointer attached to a center point and known as a "trammel." The various points at which valves should open and close for a typical six-cylinder engine are clearly shown laid out on the fly-wheel rim at Fig. 117.

Engine-Base Construction.—One of the important parts of the power plant is the substantial casing or bed member, which is employed to support the cylinders and crank shaft and which is attached directly to the motor-car frame. This will vary widely in form, but as a general thing it is an approximately cylindrical member which may be divided either vertically or horizontally in two or more parts. Automobile crank cases are usually made of aluminum, a material which has about the same strength as cast iron, but which only weighs a third as much. In some cases cast iron is employed, but is not favored by most engineers because of its brittle nature and low resistance to tensile stresses. Where exceptional strength is needed alloys of bronze are used, and in some cases where cars are produced in large quantities a portion of the crank case may be a sheet steel or aluminum stamping.

Crank cases are always large enough to permit the crank shaft and parts attached to it to turn inside and obviously its length is deter-

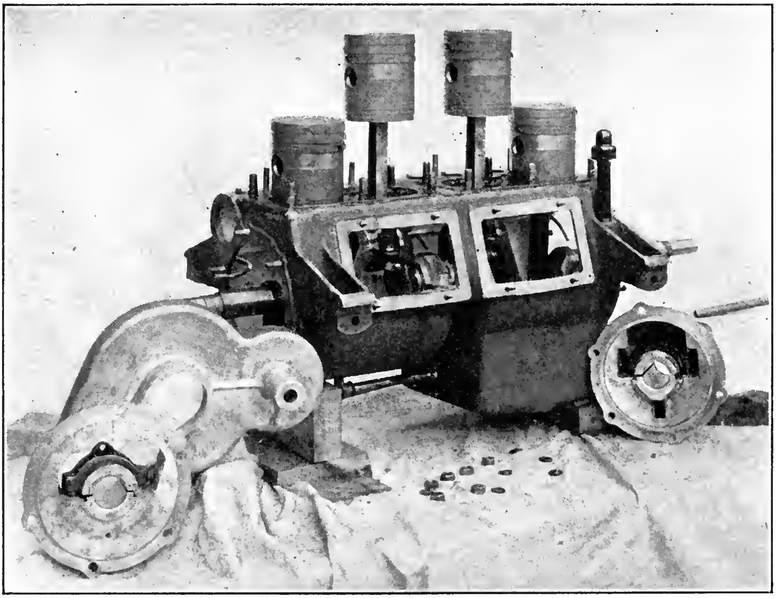


Fig. 118.—Crank Case of Reo Four-Cylinder Motor, a Barrel Type with Ends Closed by Plates which Support Crank Shaft.

mined by the number of cylinders and their disposition. The crank case of the single-cylinder or double-opposed cylinder engine would be substantially the same in length. That of a four-cylinder will vary in length with the method of casting the cylinder. When the four cylinders are cast in one unit and a two-bearing crank shaft is used, the crank case is a very compact and short member. When a three-bearing crank shaft is utilized and the cylinders are cast in pairs, the engine base is longer than it would be to support a block casting, but is shorter than one designed to sustain individual cylinder castings and a five-bearing crank shaft.

A four-cylinder crank case of the barrel type is shown at Fig. 118. The construction calls for the use of end-bearing plates, which carry the front and rear main journals. In order to gain access to the interior, large openings are provided at the side of the case and closed by plates when the assembly is completed. The cylinders are held in place by a series of stud bolts screwed into the top of the case, and a similar method of retention is utilized for the end plates. A projection from the side serves to house the cam shaft, while the motor-

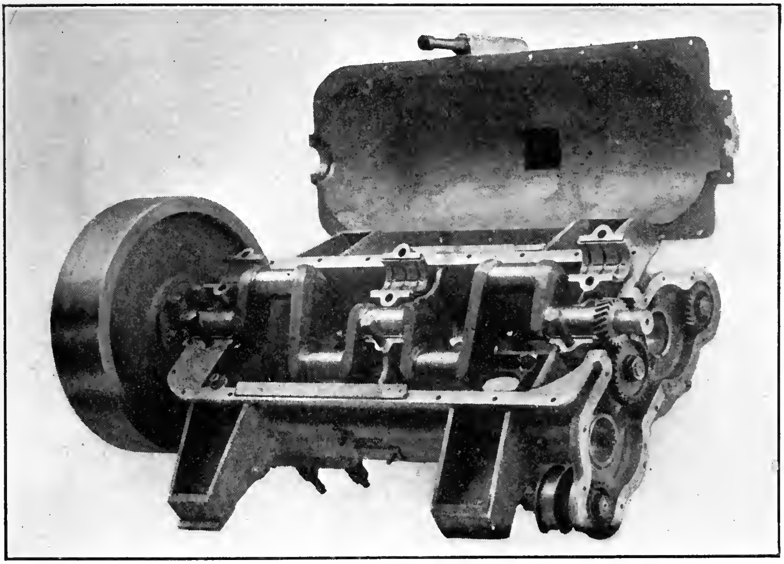


Fig. 119.—Crank Case of Corbin "40" Power Plant Made in Two Halves. Crank-Shaft Bearings and Caps Secured to Upper Half, which also Has Supporting Arms Cast Integral. Lower Portion of Crank Case Simply Acts as Oil Container. This is the Common Construction.

timing gears are protected by a separate casting member, which is part of the front bearing plate. It is now common construction to cast an oil container integral with the bottom of the engine base and to draw the lubricating oil from it by means of a pump. The arms by which the motor is supported in the frame are substantial-ribbed members cast integrally.

The approved method of crank-case construction favored by the majority of engineers is shown at Fig. 119, bottom side up. The upper half not only forms a bed for the cylinder but is used to hold the crank shaft as well. In the illustration the three-bearing crank shaft is shown resting in the upper main bearing boxes which form part of the case, while the lower brasses are in the form of separately cast caps retained by suitable bolts. In the construction outlined the bottom part of the case serves merely as an oil container and a protection for the interior mechanism of the motor.

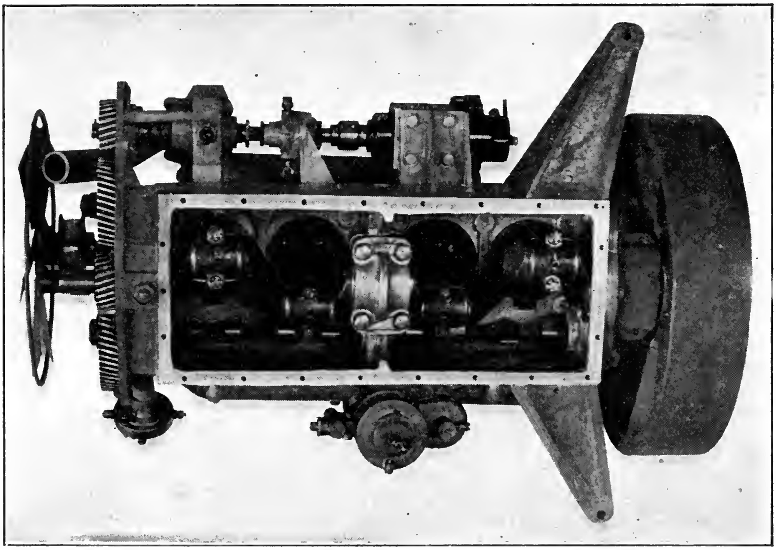


Fig. 120.—Bottom View of Inter-State Power Plant. Crank Case a Barrel Form with Removable Bottom Plate to Permit Access to Engine Interior. Important Power Plant Parts Clearly Shown.

In some instances where barrel-type crank cases are employed, instead of using hand holes for adjustment in the side, the design is as shown at Fig. 120. The bottom of the crank case is left open in casting and is closed by a large plate. The interior parts of the engine

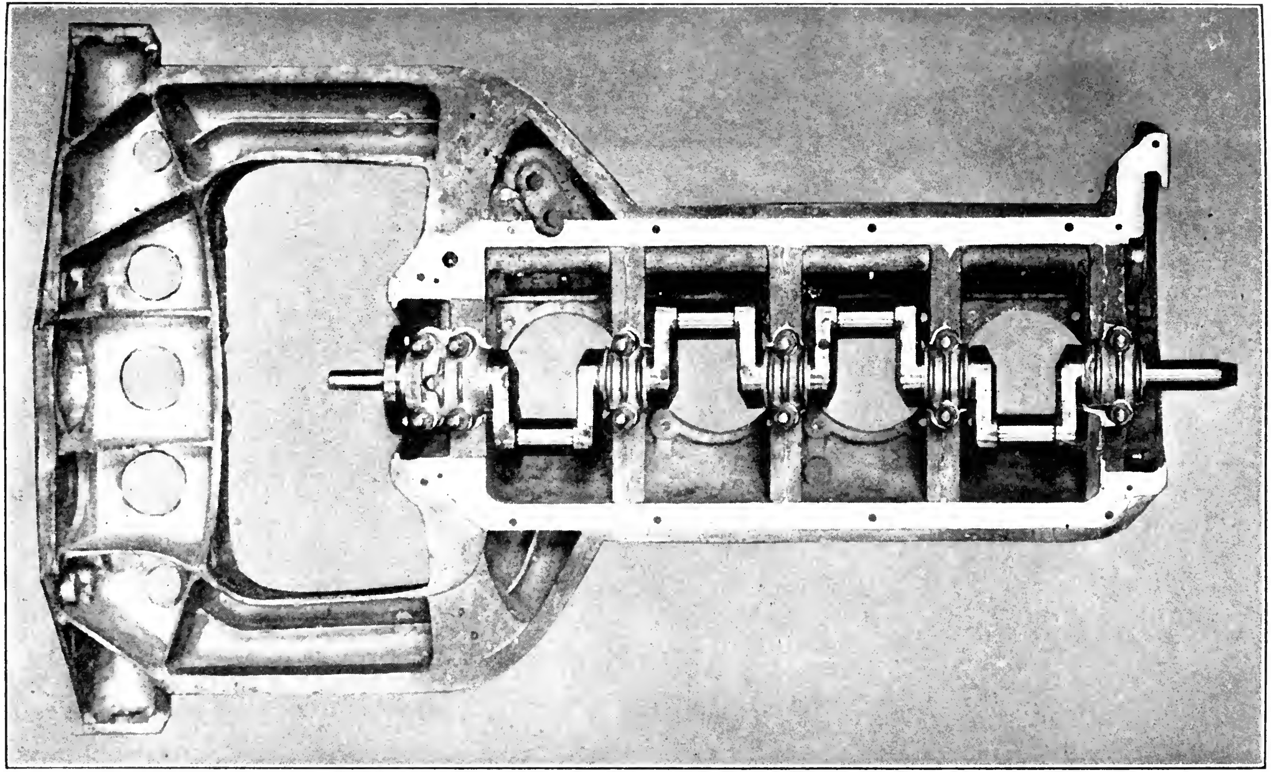


Fig. **121**.—Top Half of Knox Crank Case. Note Method of Supporting Five-Bearing Crank Shaft and Substantial Yoke-Encircling Space for Fly Wheel and Serving to Hold Transmission Gearing to Form Unit Power Plant.

are clearly depicted, as they appear viewed from the bottom, and the accessibility afforded by this design should be readily perceived. Engineers who favor unit power plants often include a portion of the crank case with the housing for the clutch and gearset. Such a construction is clearly shown at Fig. 121. It will be seen that a substantial yoke member which encircles the fly wheel is used to join the gear case to the engine base. In this view the method of retaining the five-bearing crank shaft to the upper half of the case is also shown. In designing crank cases the main thing to be considered is to have it of ample strength and to arrange the various parts so that the interior mechanism may be reached without dismantling the entire engine when adjustments are necessary.

Typical Two-Cycle Motors.—As a general rule the two-stroke cycle engines that have been adapted for automobile propulsion differ materially from the simple forms previously described. Some makers, who use the simple form, have been able to secure very satisfactory results in practice by careful attention to port design. When a two-cycle motor is to be used for motor-boat propulsion, it is a moderate speed proposition and great flexibility or efficiency are not sought. In the automobile, however, the conditions that obtain make it necessary to design the power plant in such a way that it would have a wide range of speed and so that it can be easily accelerated from its lowest to its highest speed without missing explosions or running irregularly.

A sectional view through the cylinder of the Amplex two-cycle motor is shown at Fig. 122, A. This motor is a simple construction which resembles the marine type in general design, though great care has been taken in proportioning the ports and gas passages to obtain the flexibility which is so essential to the motor-car power plant. This motor is a three-port type and the gas is taken into the engine base through ports which are uncovered by the piston when it reaches the end of its compression stroke. When the parts are in the position shown at A, the piston has reached the top of its stroke and the compressed gas in the cylinder is ready for ignition. At the same time the inlet ports just at the bottom of the piston have been uncovered and the gas flows through the intake manifold from the carburetor. In the other view shown at B, the position of the parts when the piston has completed its power stroke is depicted. The exhaust port is

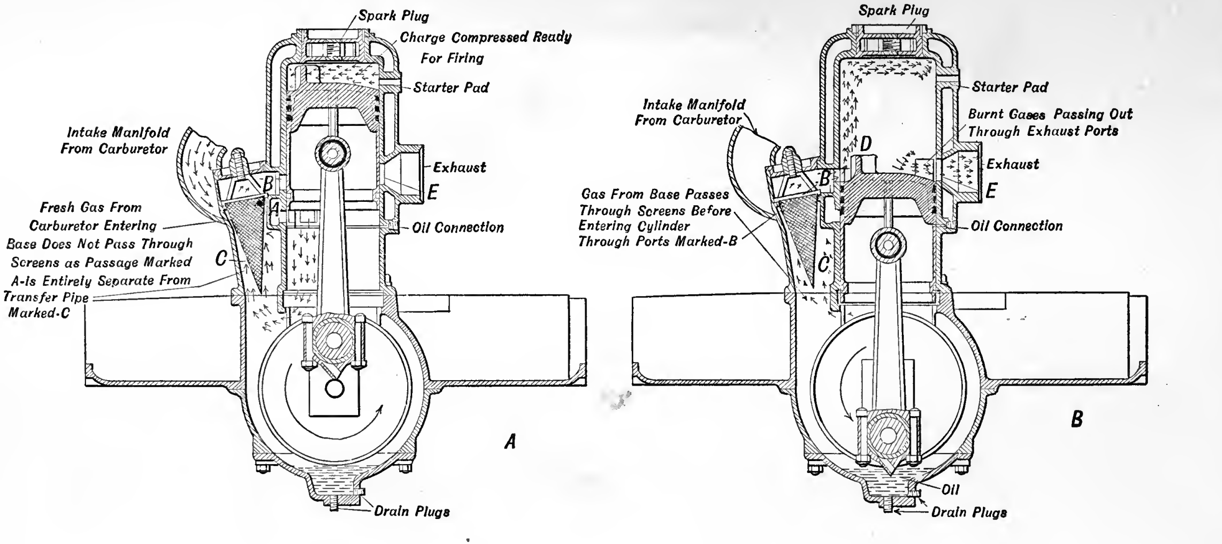


Fig. 122.—Sectional View of Amplex Two-Cycle Motor Cylinder. A—Piston at Top of Stroke, Ready to Receive Impact Due to Gas Explosion. B—Piston at Bottom of Stroke. Note Gas Transfer from Engine Base and Expulsion of Burned Gases.

fully opened and the burned gases are discharged through it. Communication is also made between the engine base where the charge has received preliminary compression necessary to insure its transfer through the safety screen and the open ports in the cylinder wall. The entering fresh gas is deflected to the top of the cylinder by the deflector plate provided on the top of the piston, as is usual practice. The Amplex motor is a four-cylinder type and gives very satisfactory results in practice.

The Legros two-cycle motor, which is of French derivation, embodies a distributor valve and a peculiar arrangement of pistons. In this construction a stationary member is placed inside of the regular working piston, and it is the space between these members that is utilized to store the gas taken in, prior to transferring it from the pump portion of the engine to the combustion chamber. The action is very similar to that of the usual form of differential piston motor. When the piston goes up on the compression stroke it draws in a charge of gas from the carburetor through the rotary distributor valve and up through the passage which joins the valve chambers to the space between the stationary and movable pistons. When the piston reaches the top of its stroke the rotary valve turns to such a position that it cuts off the carburetor from the pumping chamber and provides communication between the pumping chamber and the cylinder by means of the usual transfer passage and inlet ports cored into the cylinder wall. Otherwise the action is just the same as that of the more simple forms of engines. The construction of this motor is clearly shown at Fig. 123, and as all parts are clearly indicated the principle of operation should be easily grasped.

Another differential piston motor designed by a French engineer, Monsieur Coté, is shown at Fig. 124. In this a double-diameter piston is used and the cylinder is formed so that the smaller of these members fits the upper portion while the large end of the piston fits the correspondingly enlarged lower portion. The functions of compression and explosion of the charge take place in the smaller cylinder, while the lower member acts as a pump. On every downstroke of the piston a charge of gas is drawn into the annular space between the piston and cylinder wall, and on every upward stroke it is compressed and forced into the working cylinder adjacent. The construction out-

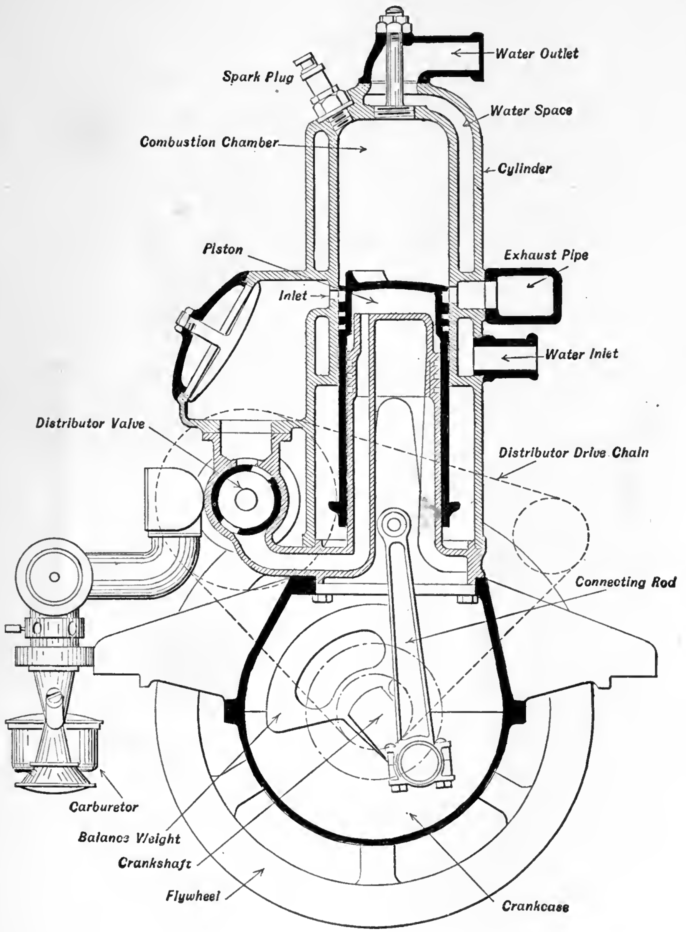


Fig. 123.—Sectional View Showing Construction of Legros (French) Motor Defining Peculiar Cylinder Construction.

lined is applicable only to motors having an even number of cylinders, and the arrangement must be such that they will work in pairs and that the piston in one cylinder will be at one end of its stroke while

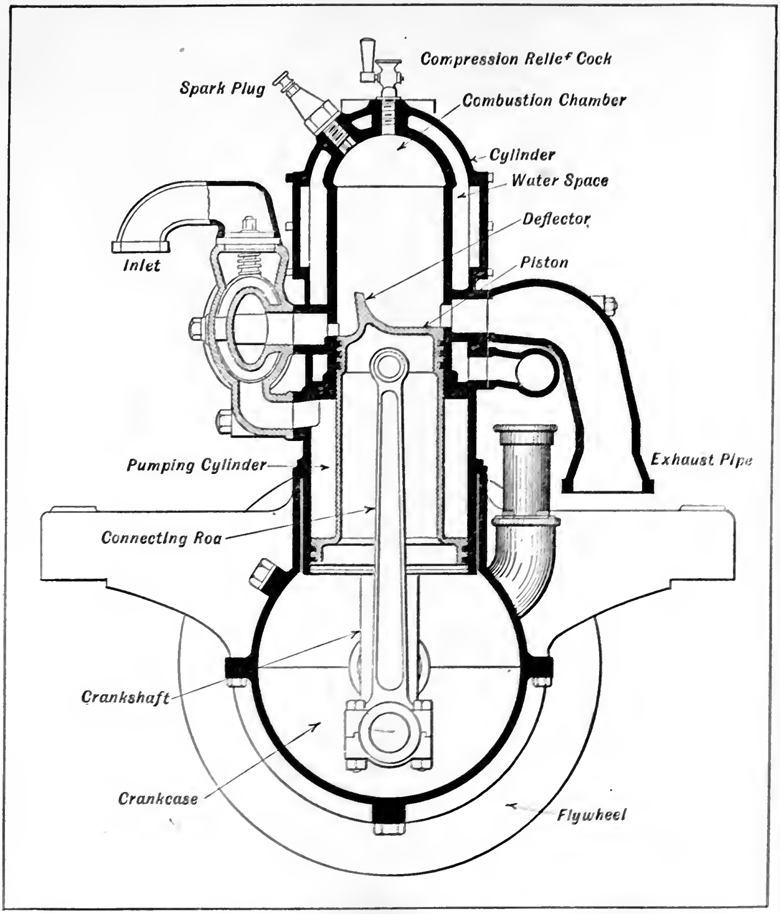


Fig. 124.—The Cote (French) Two-Cycle Motor is a Good Example of the Type Employing a Two-Diameter Piston and Distributor Valve.

that of its mate is in the other extreme position. The peculiar type of transfer passage depicted is necessary because the pumping portion of one cylinder must be joined to the working portion of the other member. Outside of peculiarities of construction, the operating cycle is just the same as other two-stroke engines, and an explosion is obtained in each cylinder every two strokes of the piston.

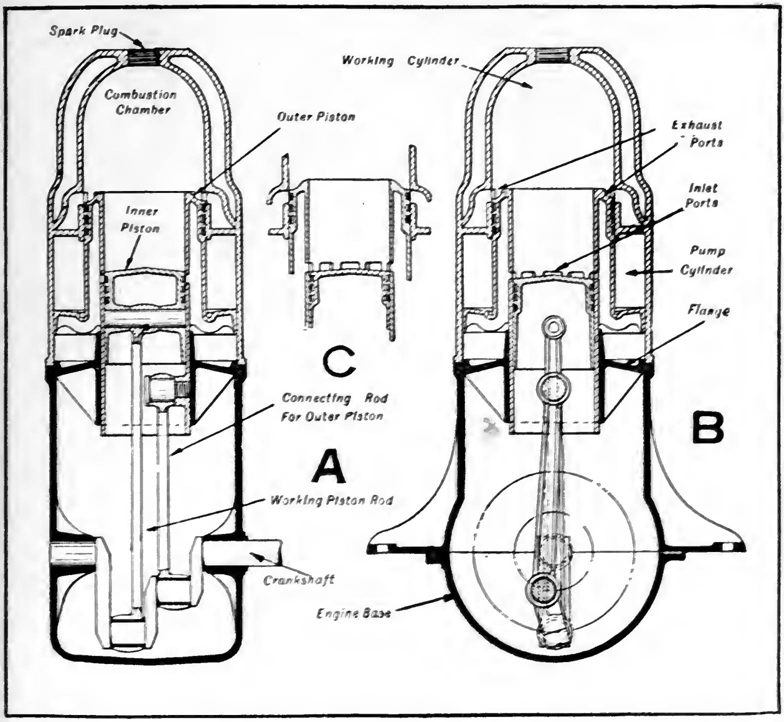


Fig. 125.—The Rayner (English) Two-Cycle Motor Employs Distinctive Double-Piston Arrangement. A—Side View Showing Crank Shaft and Connecting Rods. B—End Section Showing Relative Angularity of Connecting Rods. C—Inner Piston Uncovers Inlet Ports; Outer Piston Covers Exhaust Passages.

An unconventional two-cycle engine of English design is shown at Fig. 125. Two pistons are used, one working inside of the other: the outer member carries an annular flange which fits the enlarged bore of the cylinder and acts as a pump for taking in the gas and subjecting it to preliminary compression. The pump chamber is divided from the crank case by a flange, which also acts as a guiding member for the bottom of the large piston. At the end of the downstroke each piston uncovers a ring of ports, the outer member opening the exhaust while the inner piston controls the inlet openings. A peculiar form of crank shaft having two throws for each cylinder is used, and the crank to which the inner piston is attached has twice the amount of throw the crank connected to the larger member has. This means that both pistons work in the same direction, but that the inner member travels twice the distance the big piston does. The crank which controls the movement of the outer piston is given a lead of about twenty degrees so that the exhaust ports are opened at the proper time in relation to the opening of the inlet passages.

When the pistons travel on the upstroke, the inner one is compressing a charge previously supplied the working cylinder and simultaneously fresh gas is being inspired into the pump chamber. When the pistons reach the top of the stroke the spark takes place and the resulting explosion drives the piston down and imparts power to the crank shaft in the usual manner. At the same time that the pistons are driven down by the explosion, the new charge which has been drawn in through the pump chamber is partially compressed. Near the end of the stroke the outer piston uncovers the exhaust ports, and the burned gases escape by virtue of their pressure. The inlet ports open and new gas enters the cylinder in the usual manner and is directed to the top of the cylinder by the peculiar formation of the outer piston, which acts as a chimney to direct the gases to the top of the combustion chamber. As the new charge enters at considerable speed the high velocity of the gas forces out the burned products and insures thorough scavenging. The view at A is a side section and depicts the arrangement of the pistons relative to each other and the peculiar arrangement of the crank shaft. At B an end section is presented, this to show the angularity of connecting rods, showing how the short throw crank is given a slight lead over that which works the inner piston. The inset at C is given to enable the reader to understand the principle involved in controlling the intake and exhaust ports.

Typical Four-Cycle Power Plants.—The writer has previously mentioned the fact that most engineers favor the four-cycle form of power plant, and the majority of the descriptive matter presented in this chapter has dealt specifically with this form of engine. As a fitting conclusion a brief description of some representative American power plants will be given. At Fig. 126 the inlet side of a four-cylinder water-cooled motor is illustrated, while the exhaust side of the same power plant is depicted at Fig. 127. It will be observed that the

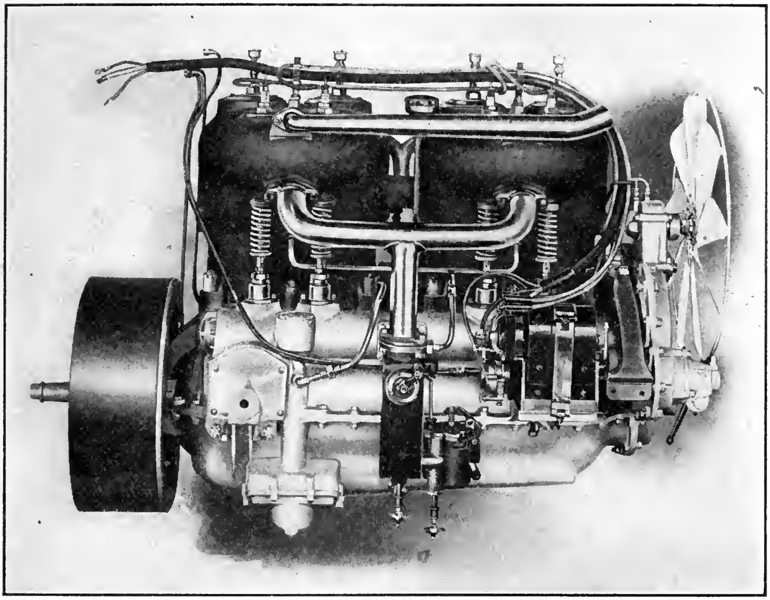


Fig. 126.—Inlet Side of Typical Four-Cylinder Power Plant Showing Carburetor and Magneto Placing.

carburetor and magneto are placed on the side of the motor with the inlet valves while the water pump is installed on the exhaust side. The front end of the power plant is supported by a steel member bolted to the upper part of the crank case, while the rear portion is fastened to the frame by means of arms cast integral with the upper half of the engine base. The cylinders are cast in pairs with water jackets integral, while the engine base is made in three pieces and is divided horizontally.

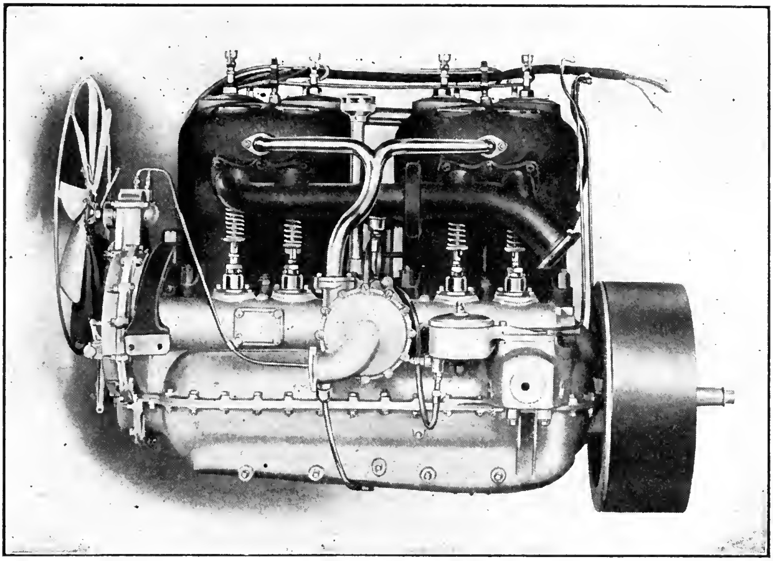


Fig. 127.—Exhaust Side of Four-Cylinder Power Plant Showing Water Pump Location.

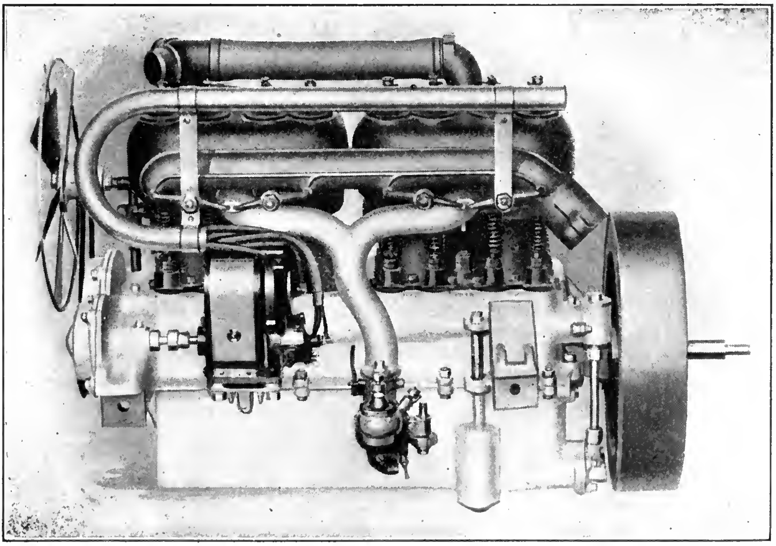


Fig. 128.—Valve Side Regal Motor Showing Compactness of Design Possible with L Cylinder Construction. Note Manifold Placing and Magneto and Carburetor Location.

The valve side of a light four-cylinder power plant used on Regal motor cars is shown at Fig. 128. This demonstrates clearly the compact design possible with "L" head cylinders, which permits placing both inlet and exhaust valves on the same side of the motor. The placing of the magneto and the method of protecting the wires leading from it to the spark plugs at the top of the cylinders, as well as

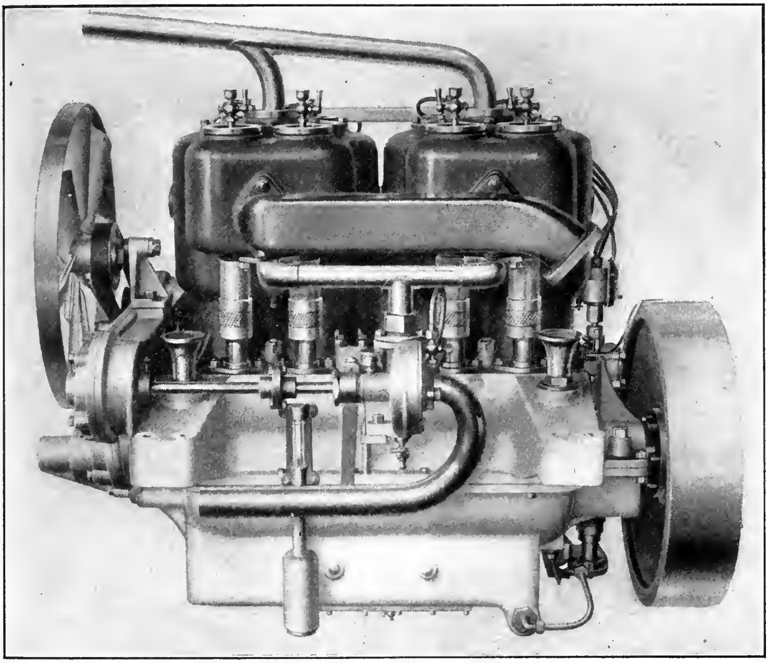


Fig. 129.—Exhaust Side of Columbia "Mark 85" Motor. Note Enclosed Valve Springs and Arrangement of Parts.

the method of retaining the inlet and exhaust manifolds, are clearly outlined. No water pump is employed on this engine, the natural or thermo-siphon system of water circulation being depended upon to adequately cool the cylinders.

The exhaust side of the Columbia Mark 85 four-cylinder motor is illustrated at Fig. 129. In this the cylinders are of the "T" head type and are cast in pairs. Attention is called to the method of enclosing the valve springs and operating plungers to keep them free of grit and to minimize noise incidental to the valve mechanism. The water pump is driven by a shaft extending from the gear case at the front end of the motor while the oil-circulating pump is suspended at the rear of the crank case between the oil container and the fly wheel.

While the greatest number of automobiles use four-cylinder power plants, there are a number of manufacturers who provide engines hav-

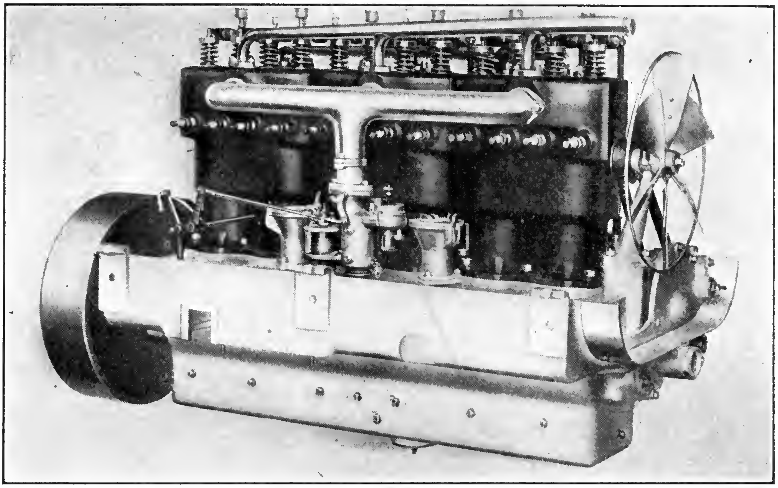


Fig. 130.—Inlet Side of Matheson " Silent Six " Power Plant, an Overhead Valve Type.

ing six cylinders. As a rule these do not differ materially from the four-cylinder forms, except for the addition of an extra pair of cylinders and the added length to the crank case that this makes necessary. The six-cylinder motor shown at Fig. 130 is a distinctive construction in which the cylinders are cast in pairs and have valves in the head. A very compact power plant is made possible by the peculiar form of the cylinder castings which have flat ends so that they can be placed very close together. It is seldom that more than six cylinders are used, but there have been automobiles made for racing purposes that had eight and even twelve cylinders.

When an eight-cylinder motor is used it is usually of the "V" type, i. e., the cylinders are arranged in two sets of four, as shown at Fig. 131. This view represents a motor which has been designed for

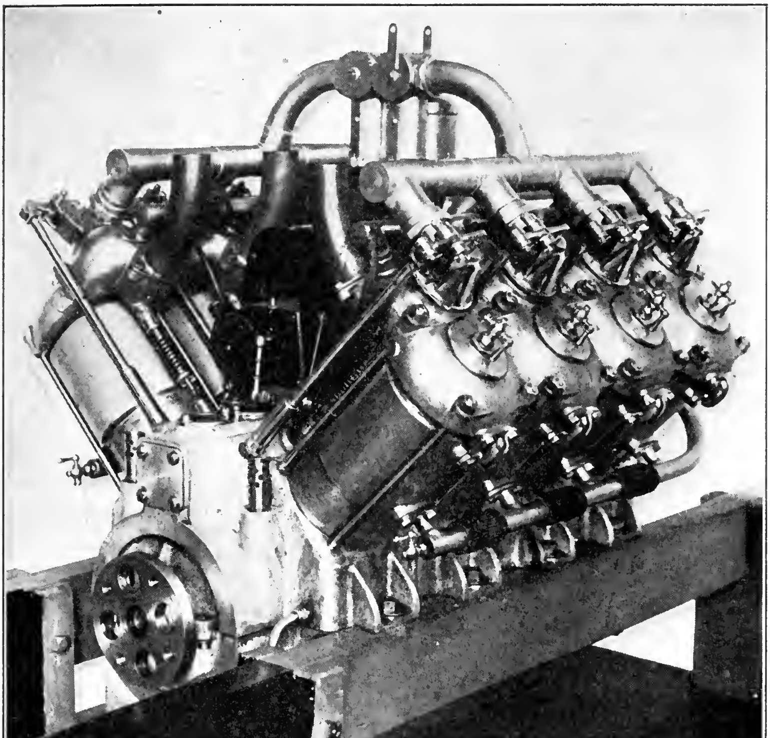


Fig. 131.—View of Eight-Cylinder Hendee Motor, a Type Seldom Used on Motor Cars, but Popular for Aviation. Eight-Cylinder Motors Designed for Automobile Propulsion are Always of the V Type, which Permits Compactness and no Greater Overall than the Usual Four-Cylinder Power Unit.

aëronautic service, but when eight-cylinder power plants are used for automobile propulsion they are built very much the same. The reason that the cylinders are arranged opposite each other and at an angle instead of being placed one after the other is that the "V" construction makes it possible to use a crank case which is not much longer or heavier than would be needed for the conventional four-cylinder motor. An eight-cylinder engine is rather complicated, and difficulties obtain in lubrication, cooling, and ignition, so that this type is not apt to become very popular, even though it furnishes power very steadily when all cylinders are working. An eight-cylinder motor of the four-cycle type will give four explosions every revolution of the crank shaft or one impulse every quarter turn. A car equipped with such a motor would be much more flexible than with a lesser number of cylinders, but as the four- and six-cylinder forms give practically a uniform and regular turning movement of the crank shaft it is not considered advisable to use more than six cylinders in touring cars and four cylinders in motor trucks.

CHAPTER V

Defining the Liquid Fuels Commonly Used and Methods of Vaporizing to Obtain Explosive Gas—Methods of Carrying Fuel in Automobiles—Development of Modern Carburetor from Early Vaporizer Forms—Elements of Carburetor Design Outlined—Typical Gasoline Vaporizers Described in Detail—How Kerosene May be Utilized—Discussing Fuel Supply by Direct Injection—Inlet and Exhaust Manifold Design—Muffler Forms in Common Use.

THERE is no appliance that has more material value upon the efficiency of the internal combustion motor than the carburetor or vaporizer which supplies the explosive gas to the cylinders. It is only in recent years that engineers have realized the importance of using carburetors that are efficient and that are so strongly made that there will be little liability of derangement. As the power obtained from the gas engine depends upon the combustion of fuel in the cylinders, it is evident that if the gas supplied does not have the proper proportions of elements to insure rapid combustion the efficiency of the engine will be low. When a gas engine is used as a stationary installation it is possible to use ordinary illuminating or natural gas for fuel, but when this prime mover is applied to automobile or marine service it is evident that considerable difficulty would be experienced in carrying enough compressed coal gas to supply the engine for even a very short trip. Fortunately, the development of the internal combustion motor was not delayed by the lack of suitable fuel.

Engineers were familiar with the properties of certain liquids which gave off vapors that could be mixed with air to form an explosive gas which burned very well in the engine cylinders. A very small quantity of such liquids would suffice for a very satisfactory period of operation. The problem to be solved before these liquids could be applied in a practical manner was to evolve suitable apparatus for vaporizing them without waste. Among the liquids that can be combined with air and burned, gasoline is the most common and is the fuel utilized by the majority of internal combustion engines employed in self-propelled conveyances.

The widely increasing scope of usefulness of the internal combustion motor has made it imperative that other fuels be applied in some instances because the supply of gasoline may in time become inadequate to supply the demand. In fact, abroad this fuel sells for fifty to two hundred per cent more than it does in America because most of the gasoline used must be imported from this country or Russia. Because of this foreign engineers have experimented widely with other substances, such as alcohol, benzol, and kerosene. The properties of these fuels, their derivation and use should be considered fully before describing the types of apparatus utilized for vaporizing them.

Distillates of Crude Petroleum.—Crude petroleum is found in small quantities in almost all parts of the world, but a large portion of that produced commercially is derived from American wells. The petroleum obtained in this country yields more of the volatile products than those of foreign production, and for that reason the demand for it is greater. The oil fields of this country are found in Pennsylvania, Indiana, and Ohio, and the crude petroleum is usually in association with natural gas. This mineral oil is an agent from which many compounds and products are derived, and the products will vary from heavy sludges, such as asphalt, to the lighter and more volatile components, some of which will evaporate very easily at ordinary temperatures.

The compounds derived from crude petroleum are composed principally of hydrogen and carbon and are termed "Hydro-Carbons." In the crude product one finds many impurities, such as free carbon, sulphur, and various earthy elements. Before the oil can be utilized it must be subjected to a process of purifying which is known as refining, and it is during this process, which is one of destructive distillation, that the various liquids are separated. The oil is broken up into three main groups of products as follows: Highly volatile, naphtha, benzine, gasoline, eight to ten per cent. Light oils, such as kerosene and light lubricating oils, seventy to eighty per cent. Heavy oils or residuum, five to nine per cent. From the foregoing it will be seen that the available supply of gasoline is determined largely by the demand existing for the light oils forming the larger part of the products derived from crude petroleum.

As a very small portion of the distillates can be used with ordinary vaporizing devices any improvements to make possible the use of less liquid or utilize the cheaper fuels, such as kerosene, will be of great value in increasing the usefulness of internal-combustion motors. Considerable attention is being given to mixing devices which will permit the use of kerosene, and many authorities have agreed that this material or alcohol will be the fuel of the future. To show the enormous consumption of gasoline in this country, it has been said that if all of the engines in use which depended on this fuel were to be operated continuously together for a ten-hour day that over five million gallons of liquid would be consumed. When one considers that the number of explosive engines is constantly augmenting it will not be difficult to perceive the reason why the development of devices to use fuels other than gasoline should be encouraged.

Benzol and Its Properties.—In England, where gasoline sells for fifty cents a gallon or one hundred and fifty per cent more than the average price in this country, engineers have sought to use benzol, which is said to be adaptable to the present types of motors without change, and in cases where it has been used as much power is obtained as with gasoline. This material is a by-product incidental to the manufacture of illuminating gas and coke, and while it was formerly distilled from coal-tar and obtained only in small quantities, improved methods make it possible to produce about three gallons from every ton of coal changed into coke or gas. The former material was at one time produced by a process which permitted the gas to escape, but at the present time this is retained and condensed to form benzol. The crude product is a foul-smelling liquid which has about the same consistency and color as heavy ale. When subjected to a refining process the dirty liquid is converted to one that is about the same color as water.

Benzol is not so volatile as gasoline, but it is claimed that a motor may be started without difficulty with this fuel supplied to a carburetor of ordinary construction. Owing to the greater number of heat units it contains, it is said it will develop more power than gasoline, and as it will not evaporate so readily it does not become stale or heavy by the vaporization of the lighter constituents. A disadvantage incidental to its use has been that owing to it being richer in carbon than gasoline it would deposit more of this substance on the piston head and interior of the combustion chamber. While this may be true of a poorly refined benzol and when mixture proportions are not correct, it applies equally well when low grades of gasoline are used and when the mixture of gasoline vapor and air supplied the cylinders is too rich.

Special Vaporizers Needed for Kerosene.—As kerosene forms one of the larger portions of the distillates of crude oil it is apparent that if this material could be used as fuel for internal combustion engines it might replace gasoline to a certain extent. If considered from a point of view of heat units contained or heating value kerosene would be a better fuel than gasoline, though considering it with its other disadvantages in mind it is not so suitable for use in existing types of motors. The chief difficulty which retards its use is that it will not vaporize readily at ordinary temperatures, and before it will evaporate sufficiently to form a gas with air it must be heated. This calls for specially constructed vaporizing devices and jacketed manifolds, which will be described in proper sequence. Owing to the low rate of evaporation it is contended that it cannot be used successfully on high-speed motors where flexibility of control is desired and where the engine must be accelerated from its minimum to the highest speed in a short time. On slow and moderate speed motors, such as used for stationary and marine service, kerosene has been employed with some degree of success. It contains more carbon in its composition, and as the combustion of kerosene vapor is not so apt to be as complete as gasoline gas, more carbon will be deposited in the interior of the combustion chamber than when gasoline is burned.

Advantages of Alcohol.—Considerable experimenting with alcohol has been done by French and German engineers, and there are many points to be considered in its favor when discussing its value as a fuel. Alcohol, instead of being derived from natural mineral deposits, which become more and more depleted as the demands increase, is derived from various plants and vegetables and is the one fuel that can be produced in quantities that could be augmented as the demand for it increased. The vegetable substances which are distilled to make alcohol are reproduced each cycle of seasons, and in tropical countries there is no cessation to the growth of the vegetation. The raw materials from which alcohol may be manufactured are found in all parts of the earth. It is derived from any substance which contains either starch or sugar, and it can profitably be produced from fruits, grains, and vegetables. It may be made from beets, sugar-cane, rice, barley, rye, corn, wheat, or potatoes, and decaying fruit or other refuse, which could not be utilized otherwise, may be subjected to a process of distillation and alcohol derived therefrom.

Alcohol differs materially from gasoline, and as it is less volatile it requires more heat to vaporize it. Alcohol vapor can be compressed to a greater degree than the vapors of gasoline, and as the heat units liberated from a fuel vary with the degree of compression even though alcohol gives out less heat when burned under the same conditions, higher efficiency may be obtained by compressing the alcohol vapor to a higher degree. While this substance has been used for a decade or more abroad, in engines designed especially for its use, it has not been applied with any degree of economy in motors designed for use with gasoline.

A motor constructed for use with alcohol must use a higher degree of compression than a gasoline motor, and a form of carburetor which will heat the mixture before it is taken into the cylinder should be used. An engine designed for gasoline will use twice as much alcohol as it does gasoline to develop the same amount of energy, though in a special motor the same amount of power will be obtained as when equal quantities of gasoline are burned in the conventional engine. One of the disadvantages of alcohol that is shared in common with kerosene is that it is difficult to start an engine when cold, as alcohol is not very volatile unless heated.

The amount of air necessary for complete combustion is roughly estimated at one third that needed with gasoline. Twice the amount of compression before ignition can be used with alcohol vapor. The range of explosive mixture proportions of alcohol and air is much greater than that possible with gasoline and air. Various authorities have stated that a compression of one hundred and fifty pounds per square inch is possible with alcohol, but it is doubtful if automobile engines will ever be built using such high degrees of compression.

A new process has been recently developed with a view of permitting one to use alcohol in engines of present design with no change except a special form of vaporizer. In this the alcohol vapor is passed through calcium carbide before it enters the cylinder. The water which is present in commercial alcohol and which lowers its efficiency as a fuel is absorbed by the carbide and the resulting chemical action liberates acetylene gas. This is very inflammable and increases the explosive value of the alcohol vapor. When the alcohol-acetylene combination is used, to obtain the same thermal efficiency as with gasoline gas, it is necessary to add water to the alcohol until a solution containing seventeen per cent water and eighty-three per cent alcohol is obtained.

This is no great disadvantage, as water costs nothing to speak of, and the increase in the bulk of the fuel nearly pays for the carbide. It is estimated that one pound of carbide is used per gallon of liquid. As the market price of carbide in lots of one hundred pounds or more is but four to five cents per pound, the only objection that can be advanced to the process is the increased complication of the vaporizing appliance. The combination of alcohol and acetylene has proved efficient on motors employing compressions as low as sixty pounds to the square inch and running as high as two thousand revolutions per minute, but when used alone the slow burning qualities of alcohol vapor has made it most efficient on slow-speed high-compression motors.

Alcohol used for fuel purposes must be rendered unfit for drinking by mixing substances with it which are not palatable, but which do not interfere with its use as a fuel. When so treated the substance is called denatured alcohol. Among the substances which may be mixed with the ethyl alcohol are wood alcohol, benzine, and benzol, and various distillates of crude petroleum. Chemists contend that it is better to use a hydrocarbon, such as benzol, than the wood alcohol, as a denaturizing substance, because wood alcohol tends to produce acetone and other compounds which are of corrosive nature and which might corrode the metal parts of the cylinder which were exposed to the effects of a by-product resulting from incomplete combustion of such a vapor.

Alcohol has the advantage in that the fire risk is less than with gasoline. The latter is a more volatile liquid than alcohol, and is more dangerous because it evaporates more readily. The flame of burning gasoline is one which radiates heat rapidly, whereas the alcohol flame does not radiate heat to such an extent. A mass of burning gasoline will generate sufficient heat to set objects at a considerable distance from it on fire. The heat from burning alcohol goes upward and exists mostly in the hot gases evolved by the flame. A gasoline fire is spread by water, whereas burning alcohol may be extinguished by it. Gasoline is much lighter than water and floats on its surface, but alcohol is so nearly the same density that it will mix with the water.

If one compares the chemical composition of alcohol and gasoline it will be found that it requires less air to burn a pint of alcohol than the same amount of gasoline. The oxygen contained in the alcohol tends to make combustion better, and there is practically no residue left in an engine burning alcohol gas. The exhaust from any of the petroleum distillates will smell strong and be smoky if an excess of fuel in proportion to air is in the mixture. The burned products of an alcohol mixture are not objectionable even if there is an excess of alcohol. These exhaust gases besides being more agreeable to the senses are cooler and cleaner, and as they contain a smaller proportion of free carbon less of this is deposited in the combustion chamber and muffler.

Among the conditions which are unfavorable to the use of alcohol and which militate against its use at the present time can be cited the present types of engines and carburetors, and the high price of denatured alcohol. While alcohol has not been extensively experimented with in this country, because the supply of gasoline at the present time seems adequate, it is expected that, should there be a shortage of this valuable commodity, forms of vaporizers will be devised which will permit the use of alcohol in connection with present-day forms of motors. Some authorities contend that alcohol will be the fuel of the future, while others believe that kerosene is more adaptable for use in the hydrocarbon motor.

Solid Gasoline as a Fuel.—Experiments are being conducted in Europe with gasoline in the solid form, which is said to have some advantages over the liquid fuels. Solid gasoline is a transparent product which is in the form of a jelly, having sufficient consistency so that it can be handled like any other solid body. It can be cut into pieces just as gelatine can, and may be conveyed in wooden or cardboard boxes. If examined under the microscope its structure is similar to that of a very fine sponge and the theory is that liquid gasoline is present in the pores. Its properties in general are the same as liquid fuels as it evaporates very easily, and has the same heat value. When solid gasoline is heated it does not melt under ordinary conditions but evaporates. If it is lighted it does not melt, but burns like wood, and the flame may be easily extinguished by covering with a piece of cloth.

Solidified gasoline has about eighty per cent the bulk of ordinary liquid gasoline; whereas a gallon of liquid will occupy a space of 231 cubic inches, the same amount solidified will occupy but about 185 cubic inches. The mixture may be easily obtained, as solid gasoline dissolves in air at ordinary temperatures and yields a combustible gas which may be used in explosion motors. Solid gasoline can be used without first converting it into a liquid and a mixture of gasoline vapor and air is formed by causing a slightly heated current of air to pass over the surface of the solid fuel. It is claimed that a very good mixture is obtained. Appliances designed for carbureting solid gasoline utilize the exhaust gases of the motor as a source of heat for securing more ready evaporation.

In the experiments made abroad a special form of carburetor was constructed to use with solid fuel. This was composed of a box with a series of pipes in its lower portion through which the exhaust gases from the engine were passed. A plate which formed the bottom of the fuel compartment which was 28 inches by 17 inches wide by 17 inches high was placed on these pipes. The solid gasoline was not placed directly on the bottom of the box but on a wire mesh screen which formed a false bottom, raised about two inches from the true bottom of the fuel compartment. Four cakes of solid fuel, each seven inches square by three and one half inches thick, were placed on the wire screen. An air inlet was provided at one end of the box, the air being drawn through the space between the bottom of the fuel box and the false bottom of wire mesh on which the fuel rested. As it passed it brushed by the gasoline which had been forced through the mesh in a form very much the same as icicles and which offered a very large surface for contact. The carbureted air was passed into a mixing box fitted with extra air openings and from thence to the inlet pipe of the motor. Four gauze screens were interposed between the mixing and fuel chambers in order to prevent ignition of the gas in the fuel compartment should the motor back fire.

When the apparatus was cold the motor did not run very well, but after it had been running for several minutes and the heating pipes raised in temperature the engine worked very well. This crude experiment showed that the ratio of weight of solid gasoline to the liquid fuel for equal work done was eighty-three and five tenths per cent, which meant that considered on a basis of weight that twenty-three per cent less solid fuel was needed to obtain the same power, and that eighty-three and five tenths per cent of solid gasoline would do as much work as one hundred per cent of liquid fuel.

It is not likely that gasoline in this form will ever be used to any extent because the carburetor used will have to be very bulky and very much different in construction from that used for the liquid. The argument that solid gasoline is safer than liquid gasoline is not borne out by facts because it will evaporate quite readily and give off vapors at ordinary temperatures. It is open to question whether a fuel can be handled easier in solid or liquid forms. It would seem to the writer that it would be as easy to pour fuel out of a can directly into a suitable container as it would be to handle it in the form of blocks. The expense of solidifying the liquid would probably be sufficiently large so that any advantages accruing would be more than balanced by disadvantages of some moment. When one considers that all motor vehicles now in use are fitted to burn liquid gasoline the difficulty experienced in attempting to put the solid fuel on the market, even if it was cheaper than the liquid form, will be readily understood.

Principles of Carburetion Outlined.—The process of carburetion is combining the volatile vapors which evaporate from the hydrocarbon liquids with certain proportions of air to form an inflammable gas. The quantities of air needed vary with different liquids and some mixtures burn quicker than do other combinations of air and vapor. Combustion is simply burning and it may be rapid, moderate, or slow. Mixtures of gasoline and air burn quickly, in fact, the combustion is so rapid that it is instantaneous and we obtain what is commonly termed an "explosion." Therefore the explosion of gas in the automobile engine cylinder which produces the power is really a combination of chemical elements which produce heat.

If the gasoline mixture is not properly proportioned the rate of burning will vary, and if the mixture is either too rich or too weak the power of the explosion is reduced and the amount of power applied to the piston is decreased proportionately. In determining the proper proportions of gasoline and air, one must take the chemical composition of gasoline into account. The ordinary liquid used for fuel is said to contain about eighty-four per cent carbon and sixteen per cent hydrogen. Air is composed of oxygen and nitrogen and the former has a great affinity, or combining power, with the two constituents of hydrocarbon liquids. Therefore, what we call an explosion is merely an indication that oxygen in the air has combined with the carbon and hydrogen of the gasoline.

In figuring the proper volume of air to mix with a given quantity of fuel, one takes into account the fact that one pound of hydrogen requires eight pounds of oxygen to burn it, and one pound of carbon needs two and one third pounds of oxygen to insure its combustion. Air is composed of one part of oxygen to three and one half portions of nitrogen by weight. Therefore for each pound of oxygen one needs to burn hydrogen or carbon four and one half pounds of air must be allowed. To insure combustion of one pound of gasoline which is composed of hydrogen and carbon we must furnish about ten pounds of air to burn the carbon and about six pounds of air to insure combustion of hydrogen, the other component of gasoline. This means that to burn one pound of gasoline one must provide about sixteen pounds of air.

While one does not usually consider air as having much weight at a temperature of sixty-two degrees Fahrenheit, about fourteen cubic feet of air will weigh a pound, and to burn a pound of gasoline one would require about two hundred cubic feet of air. This amount will provide for combustion theoretically, but it is common practice to allow twice this amount because the element nitrogen, which is the main constituent of air, is an inert gas and instead of aiding combustion it acts as a deterrent of burning. In order to be explosive, gasoline vapor must be combined with definite quantities of air. Mixtures that are rich in gasoline ignite quicker than those which have more air, but these are only suitable when starting or when running slowly, as a rich mixture ignites much quicker than a weak mixture. The richer mixture of gasoline and air not only burns quicker but produces the most heat and the most effective pressure in pounds per square inch of piston top area.

The amount of compression of the charge before ignition also has material bearing on the force of the explosion. The higher the degree of compression the greater the force exerted by the rapid combustion of the gas. Mixtures varying from one part of gasoline vapor to four of air to others having one part of gasoline vapor to thirteen of air can be ignited, but the best results are obtained when the proportions are one to five or one to seven, as this mixture is the one that will produce the highest temperature, the quickest explosion, and the most pressure.

What a Carburetor Should Do.—While it is apparent that the chief function of a carbureting device is to mix hydrocarbon vapors with air to secure mixtures that will burn, there are a number of factors which must be considered before describing the principles of vaporizing devices. Almost any device which permits a current of air to pass over or through a volatile liquid will produce a gas which will explode when compressed and ignited in the motor cylinder. Modern carburetors are not only called upon to supply certain quantities of gas, but these must deliver a mixture to the cylinders that is accurately proportioned and which will be of proper composition at all engine speeds.

Flexible control of the engine is sought by varying the engine speed by regulating the supply of gas to the cylinders. The power plant should run from its lowest to its highest speed without any irregularity in torque, i. e., the acceleration should be gradual rather than spasmodic. As the degree of compression will vary in value with the amount of throttle opening the conditions necessary to obtain maximum power differ with varying engine speeds. When the throttle is barely opened the engine speed is low and the gas must be richer in fuel than when the throttle is wide open and the engine speed high.

When an engine is turning over slowly the compression has low value and the conditions are not so favorable to rapid combustion as when the compression is high. At high engine speeds the gas velocity through the intake piping is higher than at low speeds, and regular engine action is not so apt to be disturbed by condensation of liquid fuel in the manifold due to excessively rich mixture or a superabundance of liquid in the stream of carbureted air.

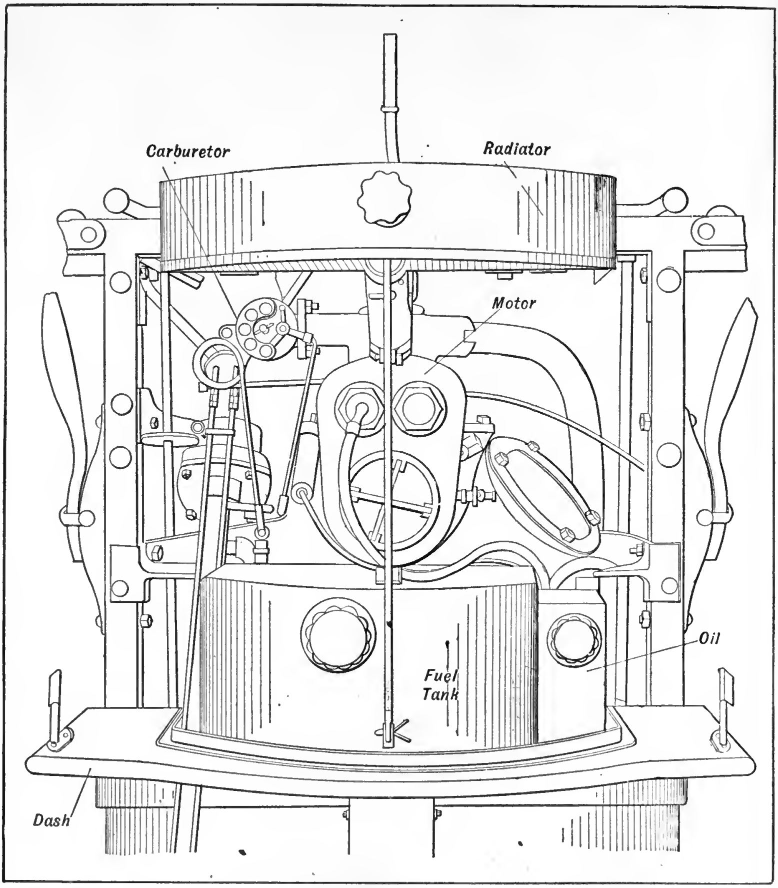


Fig. 132.—Illustrating Method of Storing Fuel in Brush Runabout, which Permits Short and Direct Gasoline Piping.

Liquid Fuel Storage and Supply.—The problem of gasoline storage and method of supplying the carburetor is one that is determined solely by design of the car. While the object of designers should be to

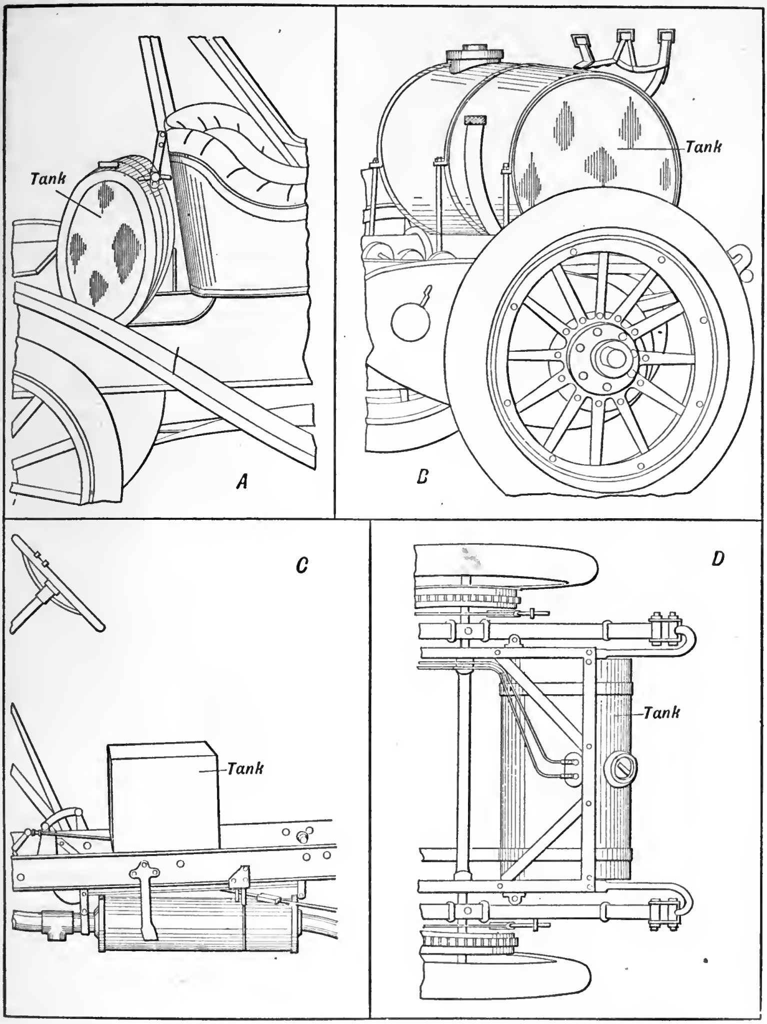


Fig. 133.—Defining the Usual Methods of Fuel Storage in Motor Cars. A—Oval Tank Back of Seat. B—Round Tank at Rear of Chassis, Common on Racing Cars. C—Container Under Front Seat, the Conventional Method. D—Tank at Rear of Frame, Underslung, which Makes Pressure-Feed Necessary.

supply the fuel to the carburetor by as simple means as possible the fuel supply system of some cars is quite complex. The first point to consider is the location of the gasoline tank. This depends upon the amount of fuel needed and the space available in the car.

A very simple and compact fuel supply system is shown at Fig. 132, which represents a plan view of the motor compartment of the Brush Runabout. The power plant in this little car is a single-cylinder engine of comparatively low power and correspondingly low fuel consumption. As it does not require much gasoline to run a small engine one can obtain a satisfactory touring radius on one filling of a comparatively small tank. In this instance the fuel container is suspended from the dashboard and is placed immediately back of the engine cylinder. The carburetor which is carried as indicated is joined to the tank by a short piece of copper tubing. This is the simplest possible form of fuel supply system.

As the sizes of cars increase and the power plant capacities augment it is necessary to use more fuel, and to obtain a satisfactory touring radius without frequent stops for filling the fuel tank it is necessary to supply large containers. The principal methods of carrying fuel are depicted at Fig. 133. At A the tank is placed back of the seats and is oval in shape. It can be easily filled, and is carried high enough above the carburetor so that the fuel will run from the tank by gravity. The tank shown at B is a cylindrical form of large capacity, and is mounted at the extreme rear end of the chassis. This member also is mounted high enough above the carburetor so the gasoline will flow to it by gravity.

In some touring cars sufficient space is provided for the reception of a fair-sized tank under the front seats, as shown at C. In this the tank is rectangular and is placed on suitable channel members so it can be supported on top of the frame. When a very powerful power plant is fitted, as on touring cars of high capacity, it is necessary to carry large quantities of gasoline. With the latest forms of bodies with low seats it is very difficult to find space enough for the placing of an adequately large tank. The usual method is depicted at D. In this the large fuel container is carried under the frame members at the extreme rear of the chassis. When installed in this manner it is necessary to force fuel out of the tank by air pressure or

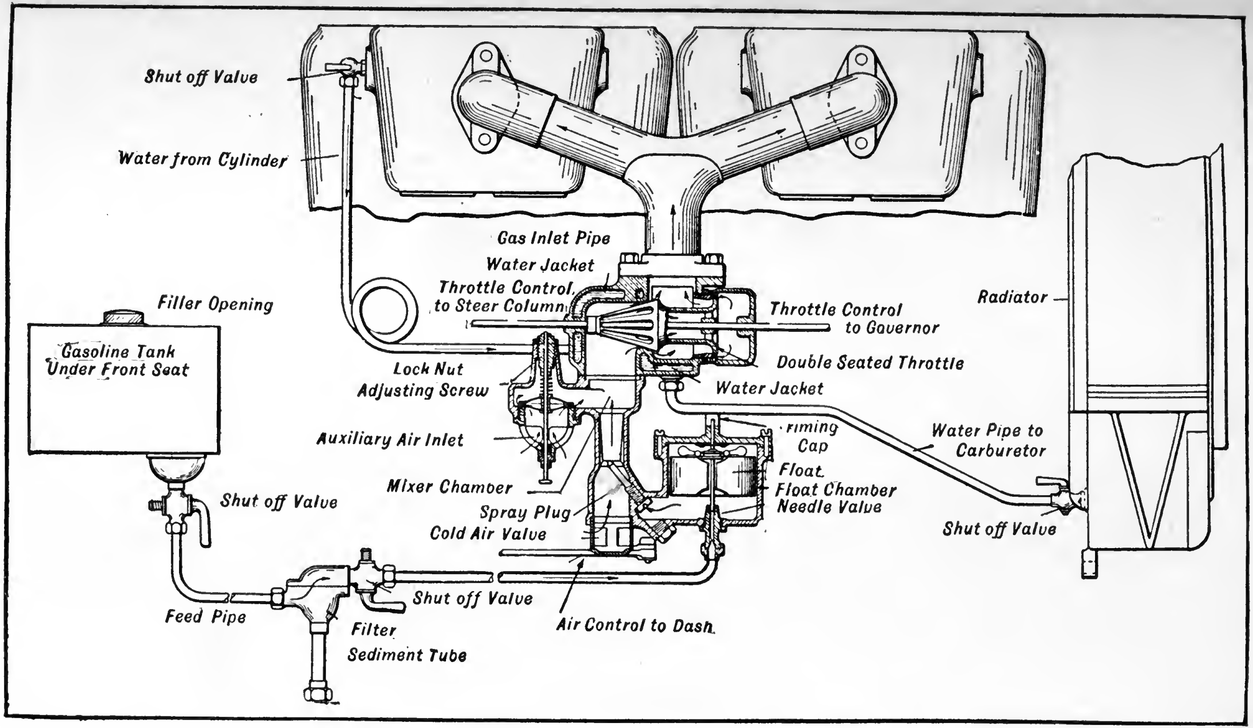


Fig. 134.—Complete Fuel System Used on Some Models of Peerless Cars, Showing Method of Supplying Carburetor with Fuel and Joining It to Cylinders.

to pump it because the gasoline tank is lower than the carburetor it supplies.

A typical fuel system in which the tank is placed under the seat, as depicted at Fig. 133, A, is shown in detail at Fig. 134. The carburetor is shown in section and is attached to the cylinders by means of a "T" form built-up manifold. The gasoline tank is joined to a filter by a short length of pipe and after the liquid passes through the filter it goes to the carburetor through a suitable length of brass or copper tubing. The filter is an important little device which removes any water, sediment, or other foreign matter from the fuel before it reaches the float chamber of the carburetor.

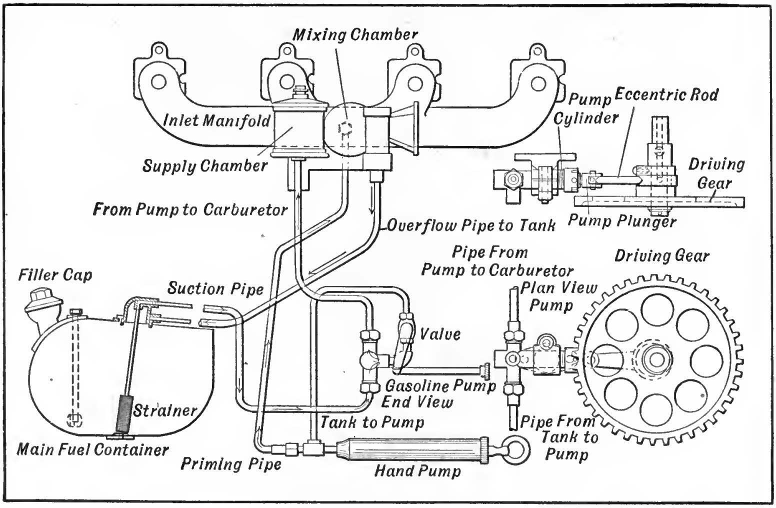


Fig. 135.—Unconventional System in which a Pump is Depended Upon to Draw Fuel from Container and Deliver It to Vaporizer.

The fuel system shown at Fig. 135 shows how the gasoline may be raised to the carburetor when the tank is placed at the rear of the chassis, as shown at Fig. 133, D. A gear-driven plunger pump takes the fuel from the tank through the suction pipe and delivers it to the supply bowl of the carburetor, which it fills to a height determined by an overflow tube. When the liquid in the supply compartment of the carburetor exceeds the predetermined level it returns to the tank through an overflow pipe. Two pumps are provided, one worked by the engine, the other manually operated. The hand pump is used in emergencies, such as for priming the carburetor or for regular supply of fuel in case of failure of the main pump.

The most common method of supplying gasoline to the carburetor when the tank is carried so low that the fuel will not flow by its weight is to pump air or gas into the supply tank and displace the gasoline by its pressure. From the main supply tank the fuel goes to a small auxiliary tank carried on the dash of the power-plant compartment. A short pipe connects this small container with the carburetor, and as this auxiliary tank is higher than the mixing device the fuel will flow by gravity. If the gasoline under pressure was fed directly to the carburetor it might result in an oversupply of fuel because there might exist pressure enough to force the gasoline into the float chamber because the shut-off needle valve would not seat positively. The auxiliary tank is generally provided with some form of automatic cut-off mechanism, which interrupts the fuel supply when the small container is nearly full.

Early Vaporizer Forms.—The early types of carbureting devices were very crude and cumbersome, and the mixture of gasoline vapor and air was accomplished in three ways. The air stream was passed over the surface of the liquid itself, through loosely placed absorbent material saturated with liquid, or directly through the fuel. The first type is known as the surface carburetor and is now practically obsolete. The second form is called the "wick" carburetor because the air stream was passed over or through saturated wicking. The third form was known as a "bubbling" carburetor. The illustrations at Fig. 136 show the principles of operation of two of the earliest forms of carbureting devices that were applied to change liquid gasoline into an explosive vapor. That shown at A consisted of a large cylinder divided into three parts by sheet metal partitions. The upper one was utilized as a fuel compartment, and this was joined to the main tank by suitable piping. The center compartment was gas storage space, and was divided from the bottom chamber by two perforated baffle plates. The lower portion of the cylinder was filled with wicking. This wicking was kept saturated with gasoline supplied from the uppermost compartment through a pipe which directed the stream of liquid against the center of the top baffle plate. As this member was provided with a large number of holes the gasoline was divided into a number of fine streams and the entire mass of wicking was saturated.

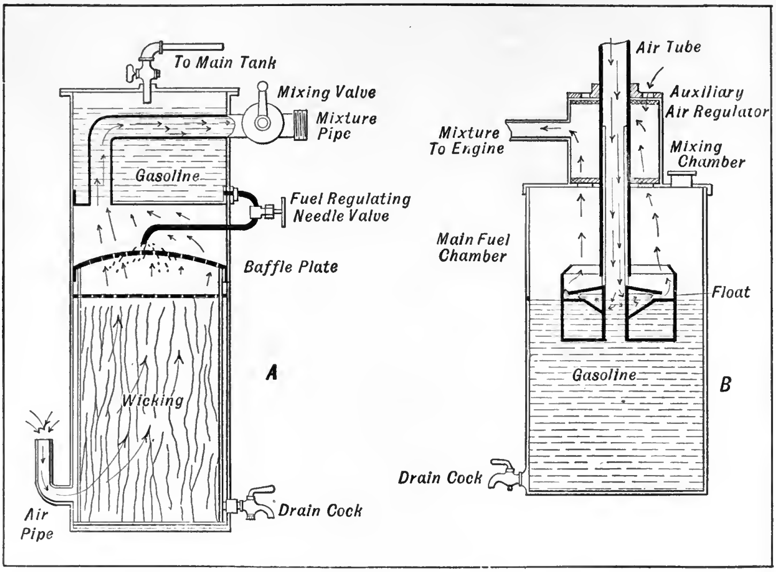


Fig. 136.—First Forms of Gasoline Vaporizers. A—An Early Wick Carburetor. B—Type in which Air is Drawn Through Fuel to Charge It with Explosive Vapor.

When the piston of the motor went down on its suction stroke air was drawn in through the air pipe at the bottom of the vaporizing device and into the center compartment or gas chamber through the wicking. In passing through this saturated material the air became charged with gasoline vapor and the resulting gas was supplied to the cylinder through the mixture pipe. This method of vaporizing the gasoline produced mixtures extremely rich in fuel and in order to burn these successfully, a simple form of valve which permitted a certain amount of pure air to enter the cylinder and dilute the rich charge was provided in the mixture pipe.

The carburetor shown at B is known as the "filtering" or "bubbling" type. This consists of two chambers: one to hold the fuel, the other utilized as a gas storage or mixing chamber. A telescopic air pipe is needed, one portion fixed to the tank, the other, or sliding member, is carried by a float which maintains a certain definite distance between a deflector plate on the pipe and the surface of the liquid. The air enters through the air tube at the top, passes down under the surface of the gasoline, and is saturated with fuel particles. The rich gas flows into the mixing chamber through screens of wire gauze and after mixing with air entering through the auxiliary air regulator, the gas passes from the mixing chamber to the engine cylinder through suitable piping.

While these primitive forms gave fairly good results with the early slow-speed engines and the high grade, or very volatile, gasoline which was first used for fuel, they would be entirely unsuitable for present forms of engines because they would not carburate the lower grades of gasoline which are used to-day, and would not supply the modern high-speed engines with gas of the proper consistency fast enough even if they did not have to use very volatile gasoline. The form of carburetor used at the present time operates on a different principle. These devices are known as "spraying carburetors." The fuel is reduced to a spray by the suction effect of the entering air stream drawing it through a fine opening.

The advantage of this construction is that a more thorough amalgamation of the gasoline and air particles is obtained. With the earlier types previously considered the air would combine with only the more volatile elements, leaving the heavier constituents in the tank. As the fuel became stale it was difficult to vaporize it, and it had to be drained off and fresh fuel provided before the proper mixture would be produced. It will be evident that when the fuel is sprayed into the air stream, all the fuel will be used up and the heavier portions of the gasoline will be taken into the cylinder and vaporized just as well as the more volatile vapors.

The simplest form of spray carburetor is that shown at Fig. 137. In this the gasoline opening through which the fuel is sprayed into the entering air stream is closed by the spring-controlled mushroom valve which regulates the main air opening as well. When the engine draws in a charge of air it unseats the valve and at the same time the air flowing around it is saturated with gasoline particles through the gasoline opening. The mixture thus formed goes to the engine through the mixture passage. Two methods of varying the fuel proportions are provided. One of these consists of a needle valve to regulate the amount of gasoline, the other is a knurled screw which controls the amount of air by limiting the lift of the jump valve.

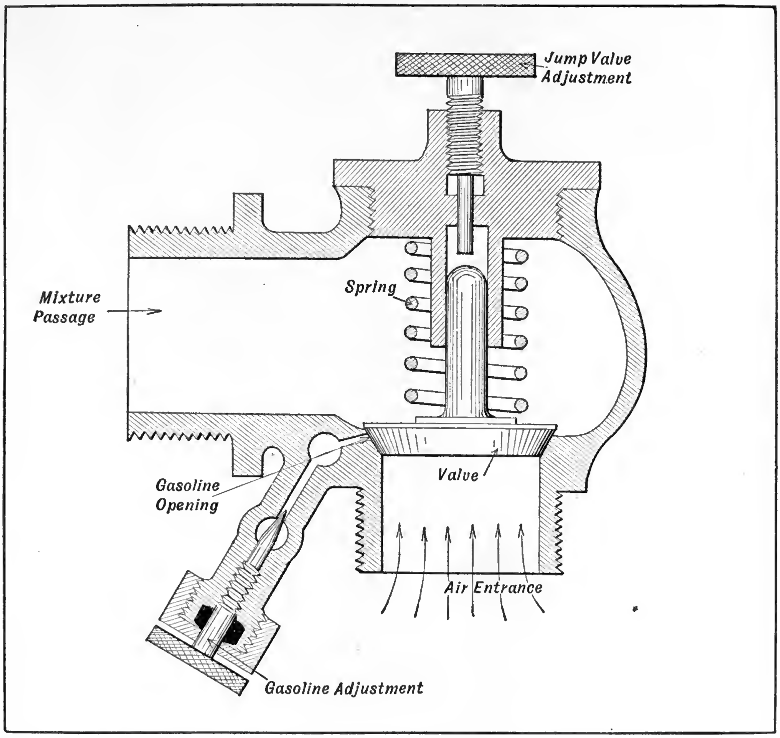


Fig. 137.—Marine-Type Mixing Valve, by which Gasoline is Sprayed into Air Stream Through Small Opening in Air-Valve Seat.

While practically all modern motor cars use spraying carburetors having automatic fuel regulation, in rare cases one sometimes finds the earlier forms of carburetors used in improved and modified types. The wick carburetor, shown at Fig. 138, is that used on Lanchester (English) cars. In this the gasoline is taken from the main tank by means of a pump and forced up through the delivery pipe into a compartment in which a number of wicks are placed. The fuel is maintained to a certain level by means of an overflow pipe which returns any excess to the tank. The entering air stream which is taken from a jacket around the exhaust pipe and thoroughly heated passes through the wicks and becomes thoroughly saturated with gasoline. It is well mixed with the liquid vapors by passing through screens which separate the wick compartment from the mixture pipes. An auxiliary air pipe and valve are provided to dilute the rich gas before it passes into the motor through the usual form of inlet manifold.

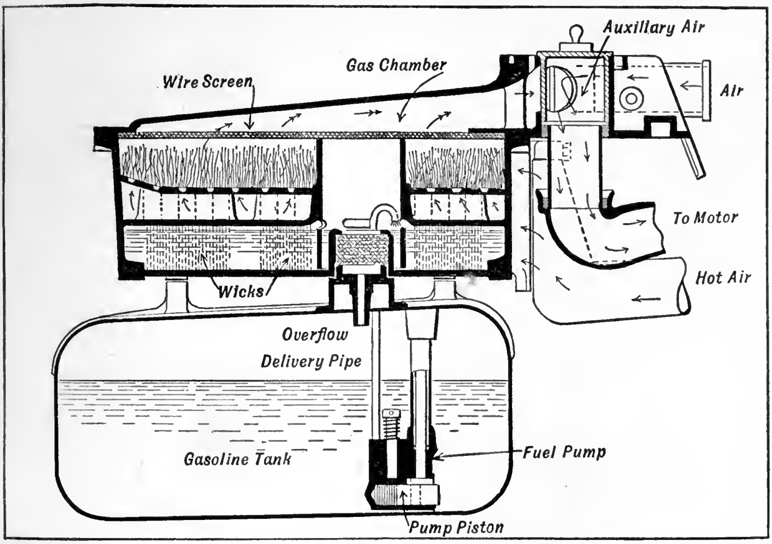


Fig. 138.—Lanchester Wick Feed Carburetor. The Only Modern Adaption of Earlier Forms.

This is the only instance at the present time to the writer's knowledge where the earlier forms of carburetors have survived. One still finds many vaporizer valves, as shown at Fig. 137, used in marine installations, though there is a growing tendency at the present time to use more modern spraying carburetors in this field as well.

Development of Float-Feed Carburetor.—The modern form of spraying carburetor is provided with two chambers, one a mixing chamber through which the air stream passes and mixes with a gasoline spray, the other a float chamber in which a constant level of fuel is maintained by simple mechanism. A jet or standpipe is used in the mixing chamber to spray the fuel through and the object of the float is to maintain the fuel level to such a point that it will not overflow the jet when the motor is not drawing in a charge of gas. With the simple forms of generator valve in which the gasoline opening is controlled by the air valve, a leak anywhere in either valve or valve seat will allow the gasoline to flow continuously whether the engine is drawing in a charge or not. The liquid fuel collects around the air opening, and when the engine inspires a charge it is saturated with gasoline globules and is excessively rich. With a float-feed construction, which maintains a constant level of gasoline at the right height in the standpipe, liquid fuel will only be supplied when drawn out of the jet by the suction effect of the entering air stream.

The first form of spraying carburetor ever applied successfully was evolved by Maybach for use on one of the earliest Daimler engines. The general principles of operation of this pioneer float-feed carburetor are shown at Fig. 139, A. The mixing chamber and valve chamber were one and the standpipe or jet protruded into the mixing chamber. It was connected to the float compartment by a pipe. The fuel from the tank entered the top of the float compartment and the opening was closed by a needle valve carried on top of a hollow metal float. When the level of gasoline in the float chamber was lowered the float would fall and the needle valve uncover the opening. This would permit the gasoline from the tank to flow into the float chamber, and as the chamber filled the float would rise until the proper level had been reached, under which conditions the float would shut off the gasoline opening. On every suction stroke of the engine the inlet valve, which was an automatic type, would leave its seat and a stream of air would be drawn through the air opening and around the standpipe or jet. This would cause the gasoline to spray out of the tube and mix with the entering air stream.

The form shown at B was a modification of Maybach's simple device and was first used on the Phœnix-Daimler engines. Several improvements are noted in this device. First, the carburetor was made one unit by casting the float and mixing chambers together in-

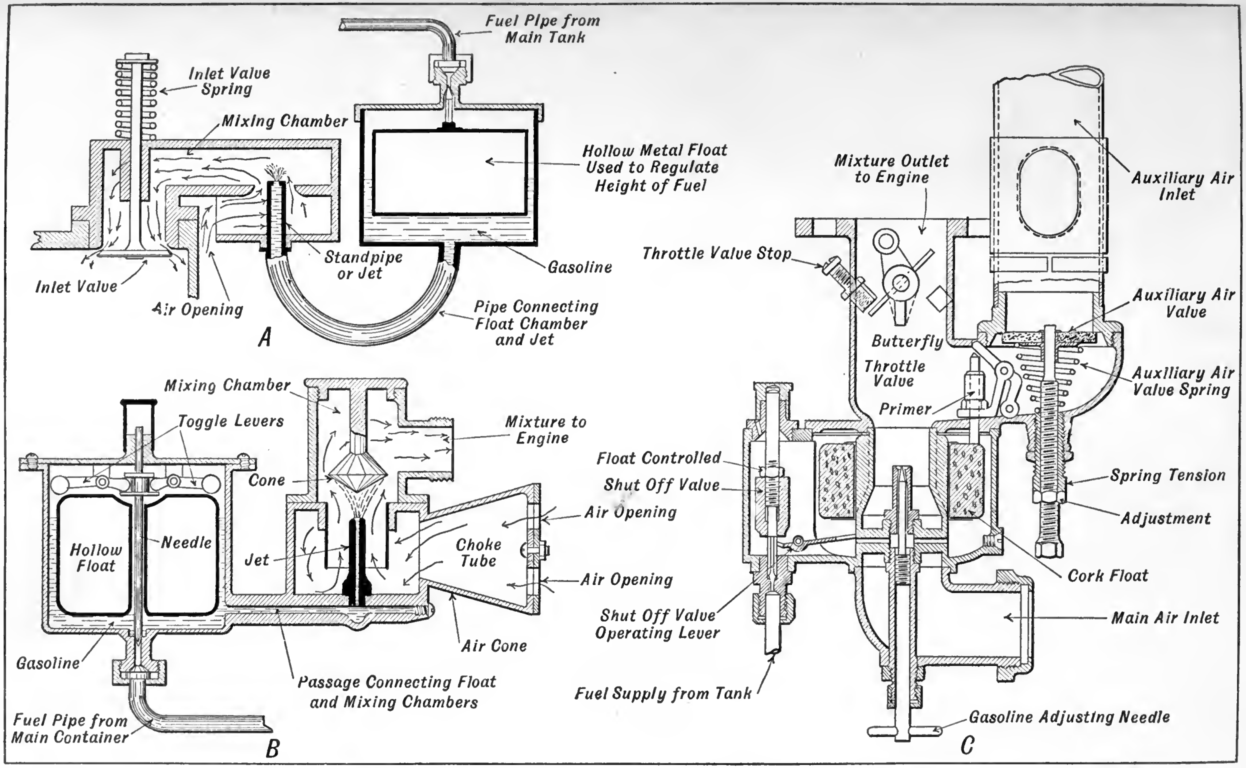


Fig. 139.—Tracing Evolution of Modern Spray Carburetor. A—Early Form Evolved by Maybach. B—Phoenix-Daimler Modification of Maybach's Principle. C—Modern Concentric Float Automatic Compensating Carburetor.

stead of making them separate and joining them by a pipe, as shown at A. The float construction was improved and the gasoline shut-off valve was operated through leverage instead of being directly fastened to the float. The spray nozzle was surrounded by a choke tube which concentrated the air stream around it and made for more rapid air flow at low engine speeds. A conical piece was placed over the jet to break up the entering spray into a mist and insure more intimate admixture of air and gasoline. The air opening was provided with an air cone which had a shutter controlling the opening so that the amount of air entering could be regulated and thus vary the mixture proportions within certain limits.

The form shown at B has been further improved, and the type shown at C is representative of modern practice. In this the float chamber and mixing chamber are concentric. A balanced float mechanism which insures steadiness of feed is used, the gasoline jet or standpipe is provided with a needle valve to vary the amount of gasoline supplied the mixture and two air openings are provided. The main air port is at the bottom of the vaporizer, while an auxiliary air inlet is provided at the side of the mixing chamber. There are two methods of controlling the mixture proportions in this form of carburetor. One may regulate the gasoline needle or adjust the auxiliary air valve. A full description of the modern types of carburetors will be given in proper sequence.

Elements of Carburetor Design.—The design of the components of modern carburetors differ largely, but most of the modern mixing devices operate on the same general principle. Certain features of design have been accepted generally, such as automatic mixture compensation by auxiliary air valves, Venturi type of mixing chamber, float and mixing chamber concentric, separate adjustment for gasoline and air, and simplicity of construction.

Automatic compensation is made necessary because a satisfactory mixture must be furnished at all engine speeds without the operator constantly varying the fuel supply or air proportions to allow for different conditions of operation produced by varying speeds. On early types of carburetors it was necessary to constantly vary the mixture proportions by working the air shutter or fuel valve from the driver's seat while the vehicle was in motion. The aim was to secure a mixture that was best adapted to the conditions of operation then present, and while a skillful driver would manipulate the adjustments in a way to deliver well-proportioned mixtures to the cylinder the average operator did not control the mixture exactly and the results obtained did not make for efficiency.

The writer has described the process of carburetion, and it is evident that the gas is supplied the cylinder by the pumping effect of the piston. The velocity of the entering gases depends upon engine speed, and as the draught diminishes it will not pick up as much fuel as when it is traveling at a higher rate. The present type of compensating carburetor provides for a sufficiently rapid flow of gas at low speed by constricting the mixing-chamber bore at the spray nozzle so that the gas speed will be sufficiently high when the engine is pumping slowly. The reduced diameter of the mixing chamber increases the velocity of the gases because the cylinder must be filled through a smaller hole in a certain unit of time than would be the case if the bore were larger. Therefore to insure a full supply reaching the cylinder the gases must pass the top of the jet at a high rate of speed even if the piston is working slowly. As the opening is constricted not enough air will be drawn in at high speed, and it is necessary to supply it through an auxiliary opening usually controlled by some automatic form of valve. This can be adjusted to open only when the suction effect is sufficiently high to overcome the tension of the spring which holds the valve to the seat, and this increased suction effect obtains only at high speeds.

The Venturi type of mixing chamber is one which is being widely used at the present time because it has properties when properly proportioned of insuring high gas velocity at low engine speed. Special care must be taken in the proportions of the air passage, as it is necessary that the area be large enough to allow the air stream to pass through freely, yet at the same time it must be constricted to such a point that the entering air stream will pass the top of a standpipe with sufficient momentum to draw an adequate supply of gasoline from the spray nozzle. The velocity of the air stream has been variously estimated, but most authorities are agreed that it should be from 7,000 to 9,000 feet per minute to insure picking up a sufficient amount of liquid as it passes around the spray nozzle.

If one compares the carburetors shown at Fig. 139, B and C, one will find that there may be two distinct forms. In that shown at B the mixing chamber is set to one side of the float compartment while at C the mixing chamber is concentric with the compartment in which the float is carried. The reason for putting the mixing chamber in the center of the float is to insure a constant level of fuel in the stand-pipe regardless of the way the carburetor is tipped. With a mixing device having two chambers, as shown at B, the level in the float compartment and the spray nozzle will be at the same height only when the carburetor is on the level. In ascending or descending hills either the float chamber will be higher than the mixing chamber or the reverse conditions obtain.

At such times that the mixing chamber is higher than the float container the level of fuel in the jet will be lower than it should be. If, at the other hand, the float chamber is higher than the jet the fuel will overflow and the mixture will be excessively rich. With a carburetor constructed as depicted at C, the spray nozzle is at a central point and the level will not vary appreciably if the carburetor tilts one way or the other. This insures an even gas supply which in turn produces uniform motor action. The engine is not alternately starved or flooded, and the mixture proportions remain practically the same.

In most cases carburetor designers believe it desirable to incorporate separate adjustments for gasoline and air, in order that all temperature variations be compensated for. When an automatic air valve is provided and the spray-nozzle opening is controlled by a needle valve it is possible to obtain a wide variety of mixtures. With this form of construction two adjustments are provided which may be used separately or worked in unison as conditions demand. Gas mixtures having proportions best adapted for low and medium speeds are usually obtained by regulating the gasoline valve, while the best high-speed adjustments are secured by altering the tension of the valve spring which regulates the air supply by restricting or increasing the lift of the air valve.

Mixing Chamber Forms Commonly Used.—One of the most important points to be considered is to provide a mixing chamber of such form that a direct passage will be provided for the charge to enter the cylinder. Any sharp angles or turns are apt to cause trouble because the gas speed will be retarded and an opportunity afforded for the condensation of fuel on sharp corners. A number of representative forms of mixing chambers are shown at Fig. 140. That at A has been very popular and the gradual curve permits the gases to flow easily. The spray nozzle is inserted at the point where the gases turn and there is no possibility of the entering air stream passing the gasoline supply pipe without picking up some fuel.

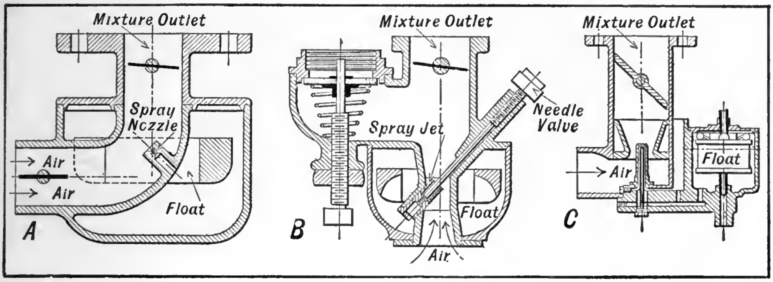


Fig. 140.—Showing Common Forms of Mixing Chambers and Spray Nozzle Locations.

The form of mixing chamber shown at B is a preferred form, as the passage for the gas is direct to the engine pipes and there is no opportunity for the collection of liquids at any sharp corner. It is apparent that the diameter of the air-pipe bore is less around the spray nozzle than it is at the point above the gasoline supply jet. This gives a Venturi effect, which is known to produce automatic mixture variations. The Venturi tube construction is valuable because it insures high gas velocity at low engine speed.

The theory of Venturi tube or constricted air passage can be easily understood if one considers the basic facts properly. When any fluid, either liquid or gaseous, passes through a tube the volume passing will be the same at all points if the bore of the pipe is constant. If gas flows through a pipe having a variable section the quantity of gas or liquid flowing through the tube remains the same, but the velocity is inversely proportional to the area of the section at different points. Therefore, if the air passage is contracted at a certain point the speed of the air stream will be greater where the area of the opening is less. As will be evident the air passage is usually constricted at the spray nozzle for reasons previously outlined.

In the form of mixing chamber shown at A no auxiliary air device is provided, but in that depicted at B an auxiliary air valve is provided at one side of the mixing chamber. The form of air passage outlined at C is not as satisfactory as the simpler forms, which provide for more direct gas flow. In this the entering air is forced to turn a sharp corner, and the resistance this offers will seriously retard the speed of the entering air stream. The form of mixing chamber outlined at B is that commonly used.

Problem of Float-Bowl Design.—Next in importance to the mixing chamber form is the problem of float-chamber design, and the mechanism which regulates the height of the fuel in the spray nozzle should be as simple and as positive in action as possible. The float and needle should be so arranged that the gasoline will be regulated in such a manner that as soon as the proper level is reached the gasoline orifice should be shut off positively. If the mechanism is made simple it is not so likely to get out of order as when more complicated methods of valve operation are provided.

The floats are made in two forms. They may be a hollow sheet-metal construction, or cork. When a hollow metal float is employed care is taken to insure that it will be absolutely tight and that fuel cannot enter its interior. Cork floats are usually coated with a shellac varnish to minimize the danger of the cork absorbing fuel. The metal float is more expensive than the cork, and if it leaks it will fill with liquid and cause the carburetor to flood. The cork float may absorb sufficient fuel to change its weight enough so that the gasoline level will be too high. It is also contended that particles may become detached from the cork float and enter the passage leading from the float compartment to the spray nozzle and clogging it or passing on further and constricting the bore of the jet.

The simplest form of float mechanism is depicted at Fig. 141, A. Here the float is pivoted at one end and carries the needle at the other. The needle closes the gasoline orifice when the level of fuel is at the right height. As soon as the level falls the float drops and the needle valve leaves its seat and permits gasoline to enter. When sufficient has been admitted to restore the level to the proper point the float rises and the gasoline opening is stopped up by the needle. The form shown at B is a modification of the simpler construction outlined at A. In this the fuel-supply needle is carried at the center of the circular float instead of at one end. The disadvantage of these simple forms in which the gasoline enters at the top of the float chamber is

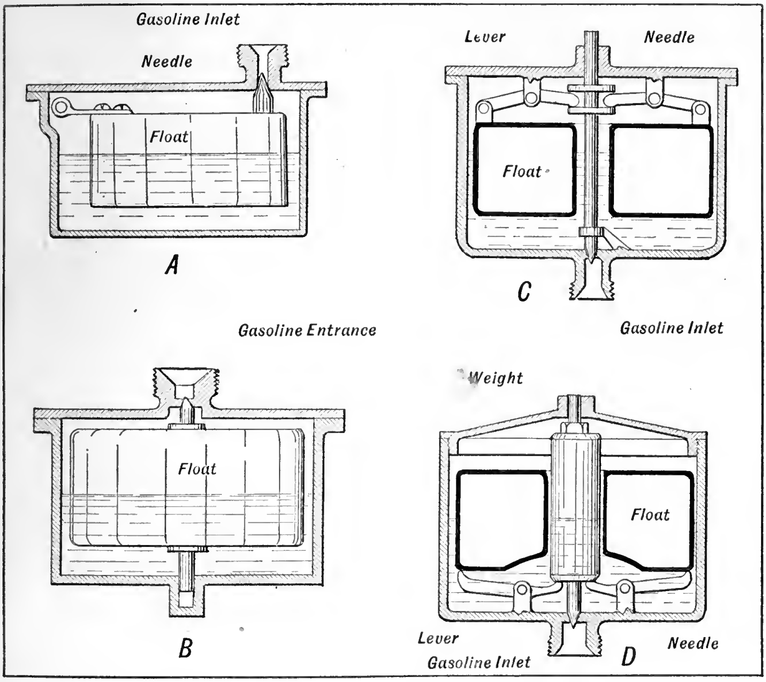


Fig. 141.—Types of Float Chambers in Common Use Defining Various Methods of Controlling Fuel-Supply Valve.

that the weight of the entering fuel which falls on the float's surface prevents the float from rising as quickly as it should, and the fuel supply is not cut off until the level is somewhat higher than it should be.

The form shown at C utilizes a hollow metal float which operates the shut-off needle through toggle linkage. As the float falls the levers reverse the movement and the needle valve is lifted, this admitting fuel through the hole at the bottom of the float chamber. A balanced float construction is outlined at D. The needle-valve stem carries a weight which tends to keep it seated in a positive manner, and with this form of weighted valve one is not apt to have the erratic fuel supply that might be caused by vibration of power plant or road on the simpler forms depicted at A and B. The float is not balanced by the weight unless the level is at the proper height, and when the fuel level falls the weight of the float which is increased in value by the system of leverage raises the needle and weight. As in the previous case, shown at C, the function of the leverage is to reverse the direction of movement. That is, the needle valve is raised from its seat when the float falls and is seated when the float rises.

Gasoline Spray Nozzle Form Important.—At Fig. 142 various forms of spray nozzles and auxiliary air valves are depicted. The simplest form is presented at A, this consisting of a standpipe having a single small hole at the top through which the fuel is discharged in a solid stream in much the same manner as water through a hose. On some foreign carburetors the standpipe is provided with a tapered plug, having series of grooves cut in its surface for the passage of fuel, as shown at B. The advantage of this construction is that the gasoline is atomized and is discharged in a number of fine streams instead of the coarser single stream. When the gasoline is discharged in a form of a mist it produces a much better mixture than when ejected in a single stream which must be broken up and divided into fine particles before it will form a homogeneous mixture. The disadvantage of the grooved plug is that the fine passages are apt to become clogged from very small particles of foreign matter in the fuel. In fact, pieces of dirt which would pass out with the stream of gasoline from the nozzle shown at A will clog the fine passages of the plug shown at B.

The amount of fuel delivered through the simple standpipe is regulated by the size of the hole, while the quantities of liquid sprayed from the nozzle shown at B can be varied to obtain different mixtures by changing the number of grooves in the plug seat. The spray nozzles illustrated at C and D are forms in which the gasoline supply is regulated by a needle valve, that at C using an overhead valve, while that at D has the needle valve adjusted from the bottom. The former construction is preferred when it is possible to apply it because it has a tendency to divide the stream of fuel into a spray or mist which is more easily vaporized.

The spray nozzles shown at C and D are used more often than those depicted at A and B because of the ease with which the gasoline

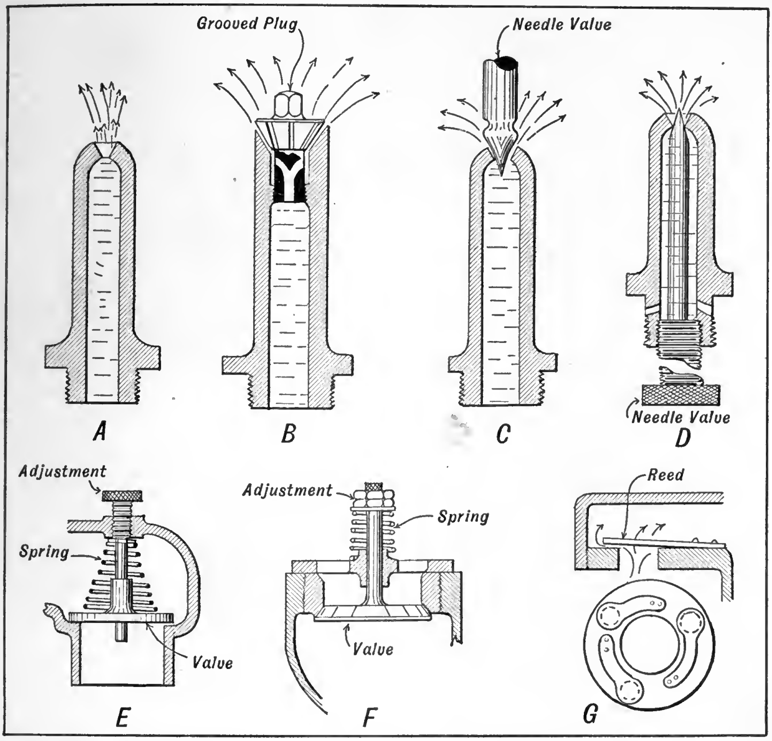


Fig. 142.—Spray Nozzle Forms and Methods of Supplying Auxiliary Air to Modern Carburetors.

proportions may be varied by screwing the needle in or out of its seat, thus reducing the size of the opening when one desires to diminish the amount of fuel or screwing it out and allowing more fuel to pass when richer mixtures are desired.

Typical Auxiliary Air Valve Forms.—Considerable difference of opinion exists in air valve construction as well, and many methods of admitting auxiliary air are used. The ordinary mushroom or poppet valves depicted at Fig. 142, E and F, are more widely applied. The former is a flat seat type kept seated by a compression spring while that at F is the ordinary form of automatic valve having a bevel seat, The disadvantage of a poppet valve is that its action is not regular, and it is apt to chatter or vibrate rapidly if the suction is not constant.

Ball and reed valves have been applied on many forms of carburetors, and it is claimed for these that they will provide an increasing supply of air as the engine speed augments without chattering or fluctuation. When a series of openings are provided instead of one large port and each of the smaller holes is regulated by an individual reed or ball it is possible to so vary the strength of the reeds, or the weight of the ball, that the air supply will be progressive.

When poppet valves are used it is customary to make these of leather or fiber so that they will not be noisy when they seat. The method defined at G is one in which reeds are used, three being provided, so graduated in strength that one alone opens at medium speed, then the other two leave their seats progressively as the engine speed augments and the suction effect becomes greater. The various forms of spray nozzles and auxiliary valves commonly used will be further described in connection with the features of the leading types of vaporizers.

Methods of Gas-Supply Regulation.—The methods of regulating the amount of gas supplied the cylinder vary to some extent, though the general system is to introduce some form of butterfly or shutter valve in the mixture pipe between the mixing chamber and the valve chamber. These valves are operated by rod connection to hand lever placed on top of the steering post or accelerator pedal on foot boards, and the amount of gas passing from the carburetor into the cylinder depends upon the amount of opening provided by the valve. When it is fully opened the gas may fill the cylinders easily, though as its position changes the area of the mixture passage is gradually decreased and the amount of gas passing through reduced.

In some cases the hand throttle is supplemented by an automatic governor which is designed to shut off the gas supply should the engine speed increase beyond a certain predetermined point. A carburetor fitted with both hand-operated throttle and shutter actuated by a governor from the engine is shown at Fig. 143. The hand throttle is a simple disk valve attached to a stem passing through the mixture pipe at a central point. When in the position shown the passage is fully opened. The governor throttle is a shutter valve placed in a special pocket above the hand-operated disk. It is worked by lever and rod connection by a centrifugal governor.

The governor consists of two weights pivoted in such a manner that they lie close to the governor shaft when engine speeds are low.

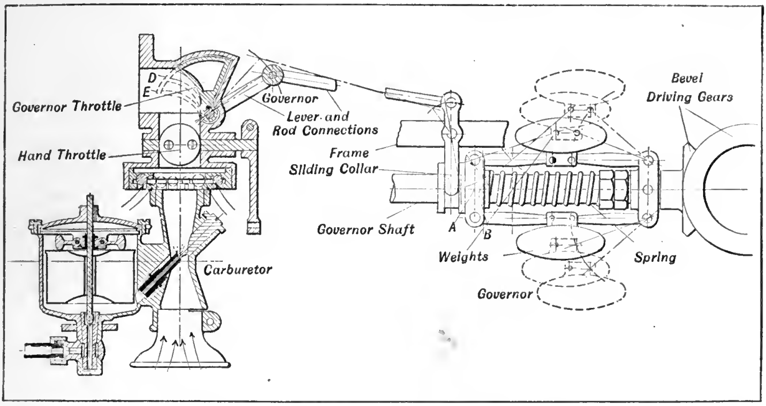


Fig. 143.—Showing Method of Regulating Fuel Mixture Supplied the Cylinders by Means of Centrifugal Governor, which Automatically Reduces the Quantity when Engine Speed Exceeds a Certain Predetermined Limit.

As the speed of the governor shaft increases the weights tend to fly out from center due to centrifugal force, and as they are thrown out they pull a sliding collar back against a spring. The sliding collar actuates a lever which closes the governor-throttle valve by the rod connecting it to the governor. The governor is driven from the engine by some form of driving gear, or it may be located on the cam shaft. The amount the weights fly out is regulated by the spring, and as its tension is increased it will take a higher engine speed to throw the weights out sufficiently to close the governor throttle. When the spring is weakened the governor weights fly out at lower speeds and the governor throttle is closed sooner.

Such a device is useful in preventing racing of the engine under certain conditions. For instance, if the car was climbing a hill on one of the lower gear ratios which would permit the engine to run quite fast and the clutch pedal was depressed so that the drive would be momentarily interrupted, the tendency of the engine, thus relieved of its load, would be to run at an extremely high rate of speed. If the operator was fully occupied in steering and shifting gears he could not regulate the hand-throttle valve and the result would be that the engine would run dangerously fast. When a governor is fitted, as soon as the engine speed tends to become excessive the weights fly out and the supply of gas is diminished automatically.

A governor is also useful on commercial cars where it is desired to keep the vehicle speed within certain limits. As speed is directly dependent upon the number of engine revolutions, the governor can be set in such a way that the engine will run up to a certain point and no faster. Governors are not so widely used at the present time as they were in the past, owing to improvements in carburetor control devices. All governors do not operate on the centrifugal principle. Some are hydraulic, others are worked by compressed air. The fly ball governor described is the most common, and as it shows clearly the principle of action and utility of such devices there is no need of considering the other forms which are so rarely found.

Construction of Modern Carburetors.—As the gasoline used in foreign countries is an imported product and is therefore more costly than it is in the United States, the foreign carburetors have been developed with a main object in view of securing maximum fuel efficiency, and minimum fuel consumption is sought rather than greater flexibility. In this country conditions have been such that the economical aspect has been somewhat neglected because at the present time the cost of fuel is really one of the smallest items to be considered in operating the average touring car. Carburetors of domestic development are not so susceptible to derangement as those of foreign derivation, but they are not so efficient and consume more fuel. The varying conditions to be met in the effort made to secure power, gasoline economy, and flexibility have resulted in a wide variety of instruments. It is apparent that these must operate on definite principles common to all, but at the same time considerable difference of opinion exists among designers and details of construction differ in almost all forms.

The Schebler Model "E" carburetor is a concentric float type, and is one of the simplest and most satisfactory of the many forms that have received wide application. The primary air inlet is through an air bend at the bottom of the carburetor, as shown at Fig. 144, and an auxiliary air inlet controlled by the usual form of poppet valve is

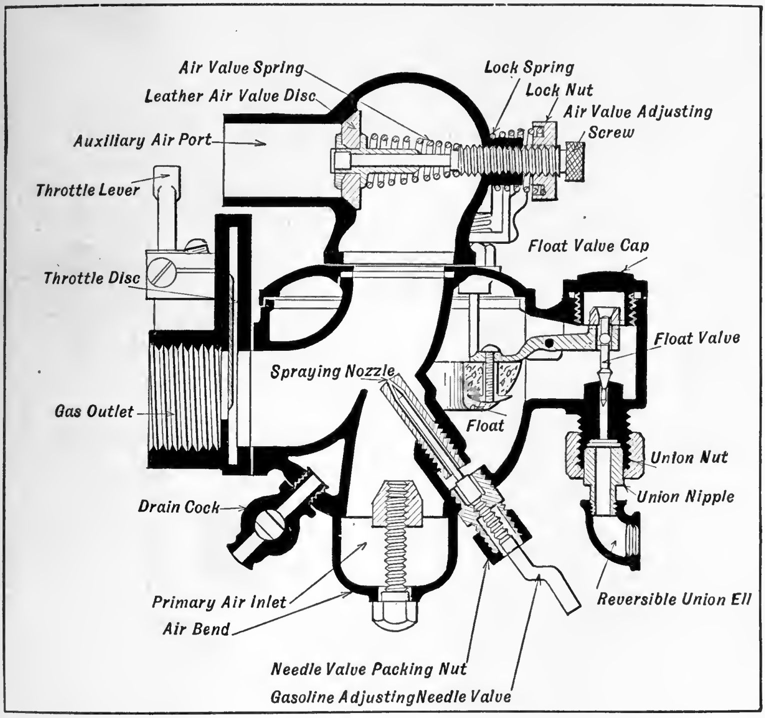


Fig. 144.—Schebler Carburetor Construction Outlined. This Is One of the Simplest Forms that Have Been Used Extensively.

provided at the top of the mixing chamber. The spraying nozzle is inserted at an angle and the amount of fuel sprayed into the mixture is regulated by a gasoline-adjusting needle. The gasoline shut-off valve in the float chamber is operated through a lever fulcrumed at its central point, the float being attached at one end while the float-control valve is carried at the other. An upward movement of the float closes the valve, which is opened as the float falls. The gasoline needle is depended upon for varying the mixture for low speed, while the auxiliary air valve takes care of high-speed mixture adjustments.

The Kingston device, which is shown in section at Fig. 145 with important parts clearly depicted, is similar in principle to that pre-

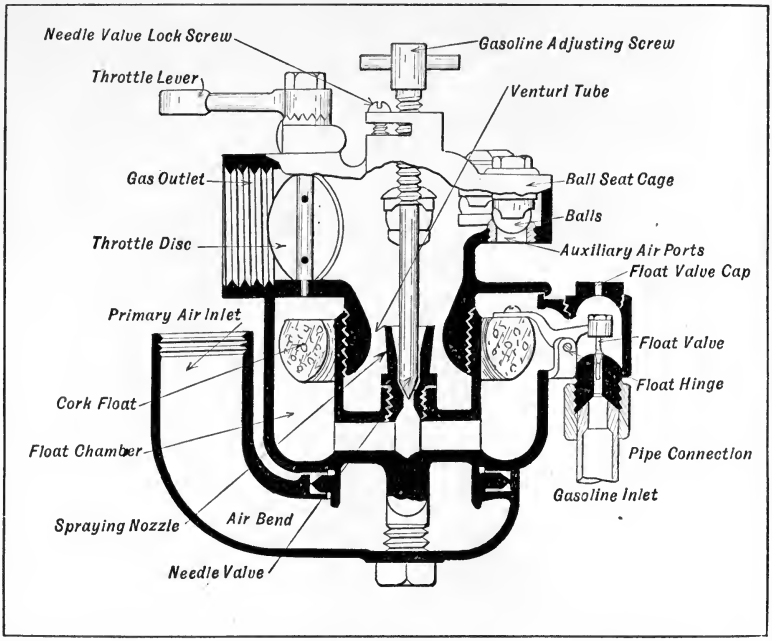


Fig. 145.—Kingston Automatic Carburetor Admits Auxiliary Air Through Ball-Controlled Ports at Side of Mixing Chamber.

viously described, inasmuch as it has a concentric float and mixing chamber and a lever-control float valve. The main air opening is through an air bend at the bottom of the carburetor, and the mixing chamber is constricted at the top of the spray nozzle to produce a Venturi tube effect. The auxiliary air ports are controlled by a series of balls of varying weight which open progressively as the motor suction increases. Fuel regulation is by an overhead needle valve, while the amount of mixture passing to the cylinders through the gas outlet is regulated by a simple throttle disk which operates on the same principle as the damper of a stove pipe. This differs from the throttle arrangement of the carburetor shown at Fig. 144, as that member is composed of a movable plate which has an up-and-down motion instead of the oscillating motion of the damper form. The throttle of the former type is known as a "butterfly valve," while that shown at Fig. 144 is a simple shutter type.

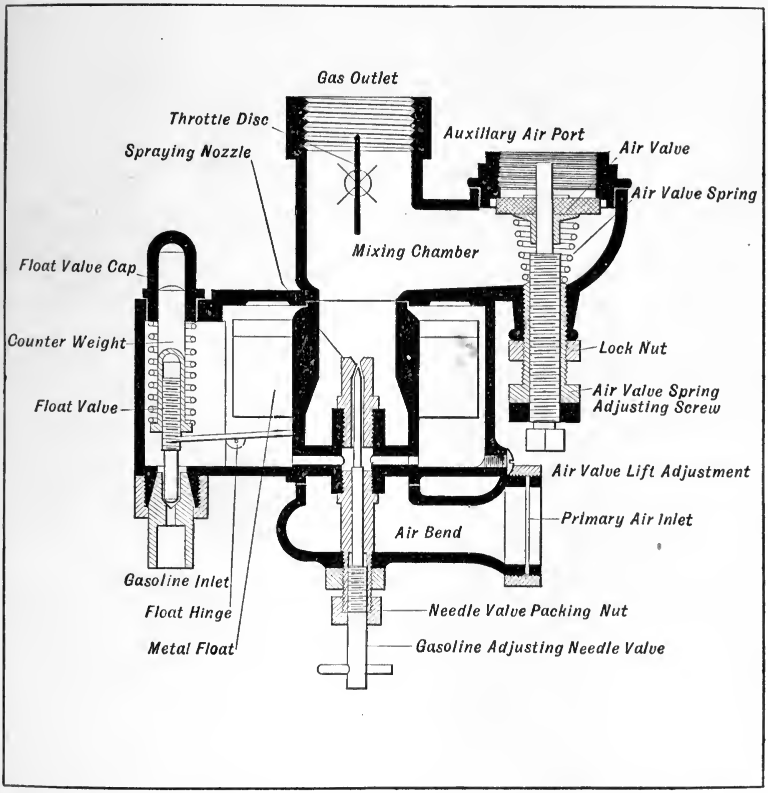


Fig. 146.—Holley Carburetor with Spring-Controlled Poppet Valve to Regulate Auxiliary Air Passage.

Another simple type of vaporizer which has given very good results in practice is shown in section at Fig. 146. This is a concentric float design having the auxiliary air port closed by a flat-seated valve.

The gasoline control member is a balanced valve having a counterweight which tends to prevent vibration. The mixture proportions are regulated by a gasoline-adjusting needle valve at the bottom of the carburetor and the air valve spring tension adjustment. The mixture delivered to the cylinders of the motor is regulated by a simple form of throttle disk.

A later and improved form of Holley Carburetor is shown in section at Fig. 147. In this the main air enters through a pipe at the side of the carburetor which communicates with an annular chamber surrounding the mixing tube. The gasoline collects in a small basin at the top of the partition separating the float bowl from the mixing tube. The gasoline supply is regulated by the usual form of needle valve at the bottom of the float bowl. In this carburetor the only moving part is the float and the auxiliary air valve or auxiliary air openings have been eliminated by a special construction of the spray nozzle.

Referring to the lettering on the drawing the action of this form of carburetor can be easily understood. The fuel from the tank enters the float chamber A to the gasoline filter screen B, and the level is regulated by the inlet valve C, which is actuated by the usual float and lever combination D. When the motor is not running the level is halfway up the cup E and submerges the lower end of the low-speed tube F. When starting the engine the throttle G is nearly closed and gasoline and air are drawn through F with very high velocity owing to the degree of suction, thus forming a rich mixture and making starting easy. The tube F continues to supply the motor at low speeds, but as the throttle valve opens the small tube gradually emerges into the larger one and all the mixture supplied at motor speeds above 300 R. P. M. passes through the main mixing tube H.

The spray nozzle I has a slot J which is supplied by two separate channels, the series of holes M and the plug L, the latter having a limited hole. At low engine speeds both operate, M predominating, but as the speed increases the fuel level automatically drops, because the needle C must lift higher with the increase in amount furnished. The leverage is about three to one, so that the float drop is three times the movement of the needle, and the holes M are uncovered to the atmosphere above the fuel surface, which passes through the slot J and maintains the uniformity of the mixture. The gasoline feed at low speeds is adjusted by the size of the plug opening O, extreme high speeds by the area of the orifice in plug L, and the intermediate

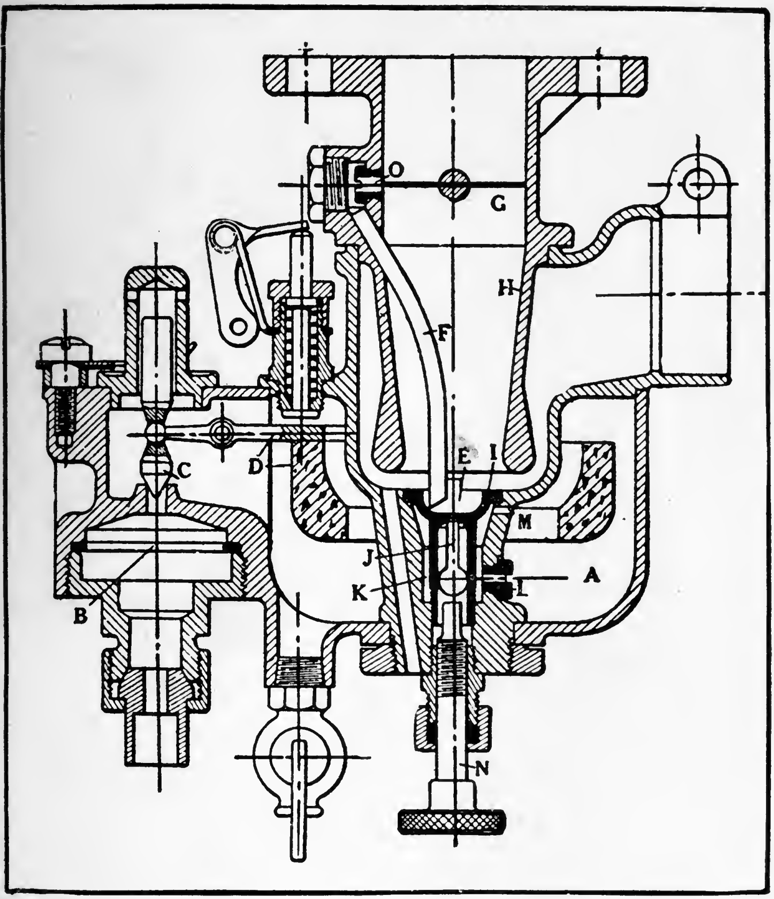


Fig. 147.—Latest Model of Holley Carburetor with By-pass Tube to Provide Easier Starting.

ratios through the automatic action provided by the series of holes M, the slot J and the nozzle I, and the adjusting needle. The advantages claimed by the designer are: permanent adjustment, positive starting, due to high vacuum and air velocity directly applied to the source of fuel supply; positive action at low and idling speed due to rich mixture; greater economy and rapid acceleration, owing to more homogeneous and better-proportioned vaporization. A richer mixture is automatically obtained for hill climbing and hard pulling because the fuel level rises with slower motor speed and feeds the spray nozzle through two channels instead of one.

A typical foreign type of simple carburetor is shown at Fig. 148, this being the vaporizing device used on Mercedes cars. This is a float-

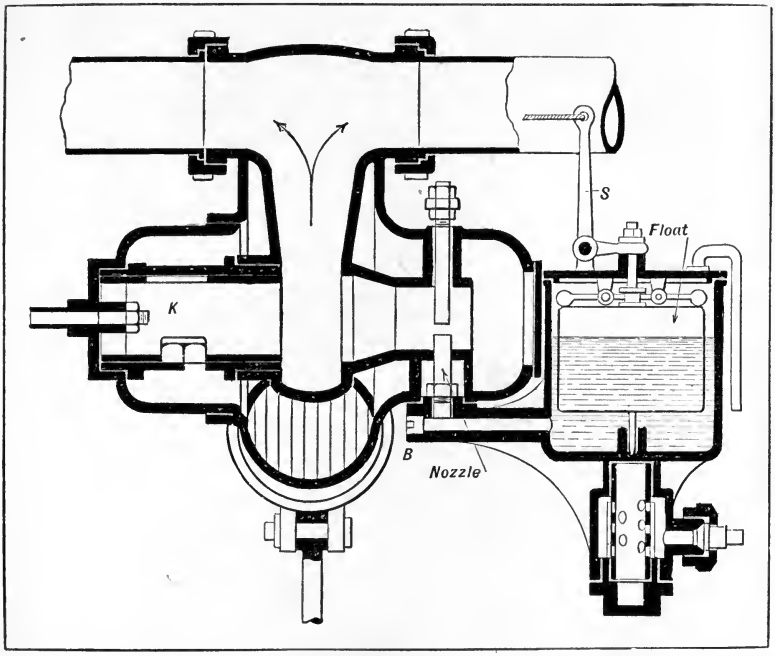


Fig. 148.—Mercedes Carburetor, which Has Retained Substantially the Same Form as when First Designed Nearly a Decade Ago.

feed type having a float chamber carried at one side of the mixing chamber. The spray nozzle is a simple type which extends in a tube having one end open to the main supply pipe and the other to the annular chamber through which the air is inspired. The mixture supply is regulated by a sliding throttle valve K, which also provides the auxiliary air in increasing proportions as the amount supplied the cylinders is increased. The only way the gasoline proportions may be altered is by varying the spray nozzle or changing the level of the float.

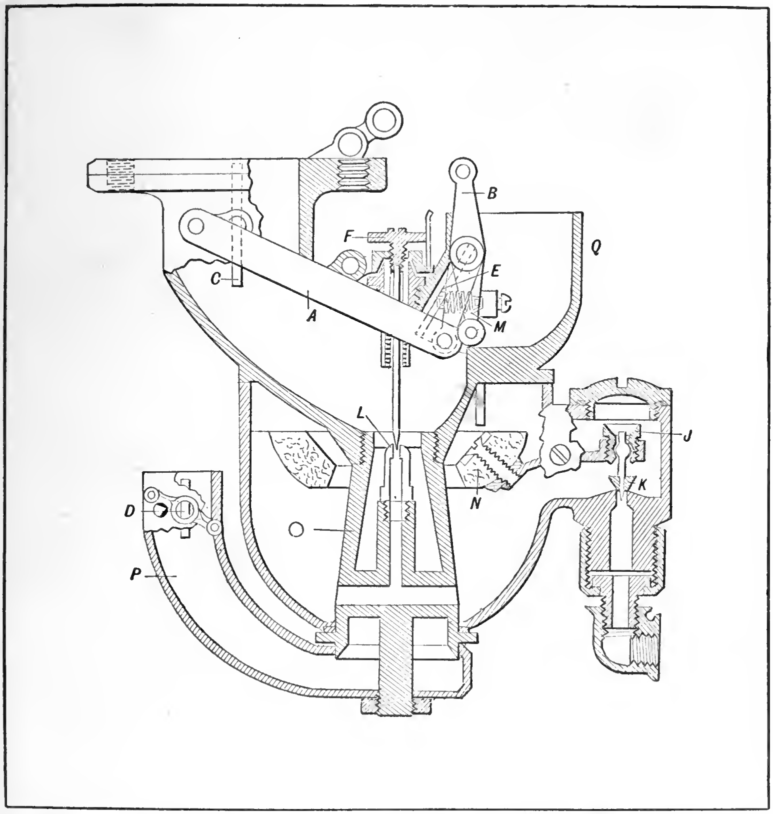


Fig. 149.—Sectional View of Chapin Carburetor, which Has Mechanical Control of Auxiliary Air Opening and Spray Nozzle Needle.

The carburetor shown in section at Fig. 149 is a type which has no auxiliary air valve, the auxiliary air opening being controlled by a valve which is directly actuated by a mechanical connection between the throttle disk so that as the throttle is opened more air is allowed to flow through the auxiliary opening. The main air enters through the air bend at the bottom and passes around the spray nozzle, which is placed at the point of least area of the air tube. The amount of gasoline supplied the mixture is regulated by the fuel needle F, and this is raised by leverage from the throttle so that more fuel is sprayed into the mixture at higher motor speed. In other respects the carburetor is a conventional construction.

The Excelsior carburetor, which is shown in section at Fig. 150, has several distinctive features, one of these being the floating ball

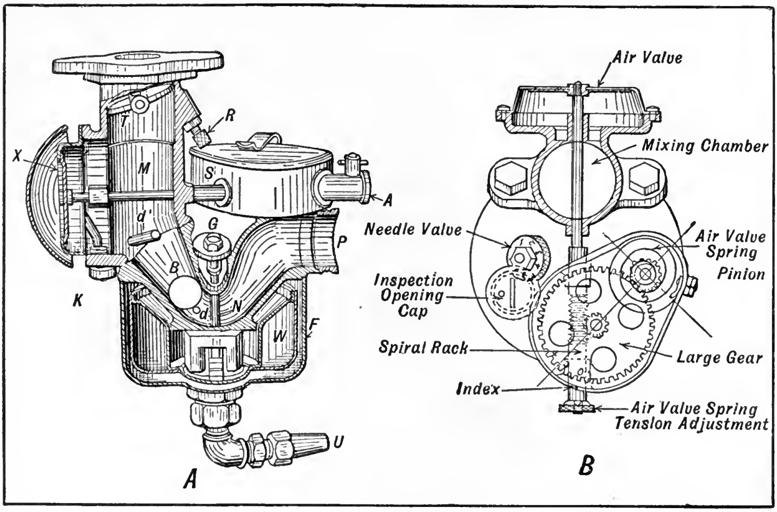


Fig. 150.—Sectional View of Excelsior Carburetor. A—Side Section Depicting Floating Ball Controlling Mixture Passage. B—Showing Peculiar Air Valve Spring and Geared Control of Air Valve Stem.

in the air tube and others exist in the peculiar form of auxiliary air-valve mechanism. It is claimed that the ball which rests against the pin D, shown in sectional view A, constricts the bore of the air tube at low speed so that the velocity of the air passing the spray nozzle is sufficiently high to insure taking up the proper amount of gasoline, but no more than that required to insure positive action of the engine. At highest engine speed the floating ball is drawn up against the stop pin D, and the air passage is practically free from any interruption. Under this condition the Venturi tube is permitted to exercise its function and a correspondingly large amount of gasoline is drawn from the spray nozzle. It is claimed that the floating ball controls the mixture automatically in that it permits the motor to get just the amount of gasoline it needs and thus conduces to economy.

The auxiliary air valve is controlled by a clock spring the tension of which is multiplied by a series of gears. The tension is extremely light when the valve is closed and increases as the valve opens. It is claimed that this form of spring cannot vary and that it will maintain its tension indefinitely. The air valve stem is provided with a spiral rack at one end which meshes with a small pinion controlled by the air valve spring. Any movement of the light air valve is multiplied many times by the gearing so that the spring tension may be comparatively light.

The carburetor is a concentric float type and with the exception of the floating ball in the air tube and the peculiar form of air-valve mechanism it does not differ from conventional practice. Referring to sectional view A at Fig. 150 the principle of action can be easily understood. The fuel enters the float chamber F through connection U and a constant level is maintained by the float valve, which is directly actuated by the hollow metal float W. The primary air enters at P and is drawn by motor suction past the spray nozzle M located in the restricted portion of the Venturi tube. The amount of gasoline admitted to the mixture is adjusted by the fuel-regulating needle G, while the amount of movement of the auxiliary air valve X may be controlled by the air valve spring tension adjustment shown in top sectional view at B. The mixture supplied to the cylinders is governed by the usual form of disk throttle valve T. To insure easy starting the stop K may be turned so that the air valve is held closed, this making for strong suction through the restricted portion of the Venturi tube and insuring easy starting by providing a rich mixture.

The carburetor shown at Fig. 151 is that used on Pierce cars, and is illustrated because it presents a number of novel features. While the construction in the main follows conventional practice inasmuch as the spray nozzle is concentric with the float, it employs a novel method of auxiliary air valve control and a form of throttle which is

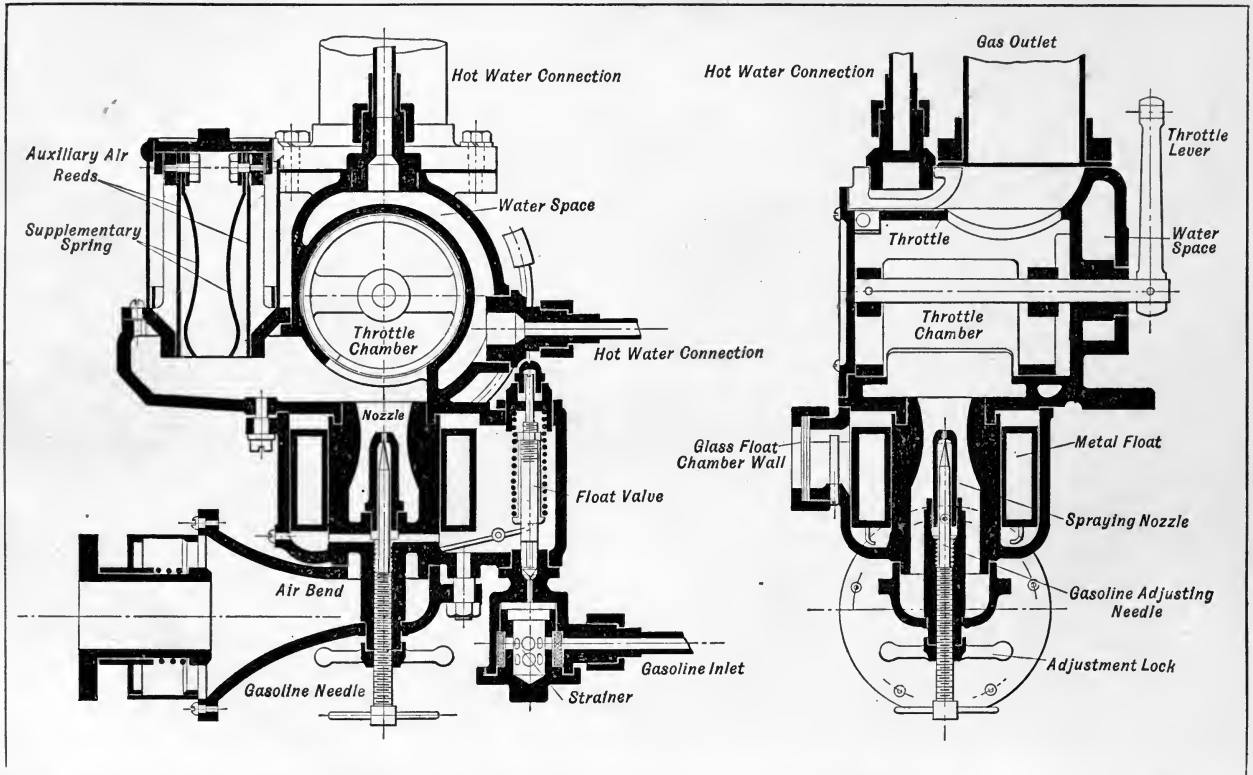


Fig. 151.—Views of the Efficient Vaporizer Used on Pierce-Arrow Cars, Showing Method of Fuel Regulation, Auxiliary Air Control by Reeds, and Mixture Supply Regulation by Cylindrical Throttle Valve.

not generally used. The auxiliary air ports are regulated by reeds which are backed by supplementary springs to prevent excessive motion. The reeds open progressively as the suction increases. The throttle chamber contains a barrel-shaped throttle member which has

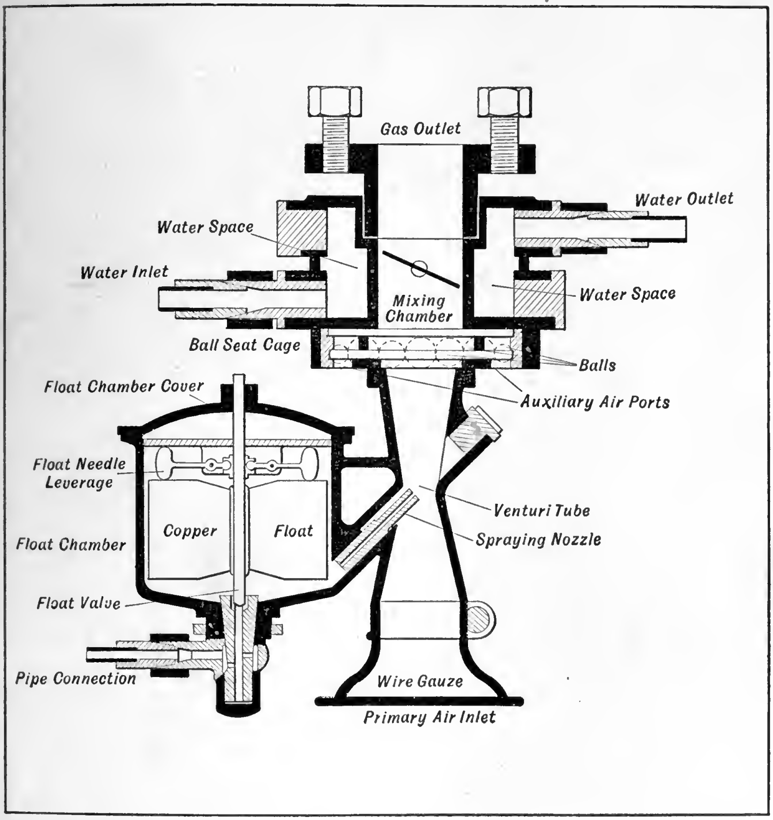


Fig. 152.—Grouvelle and Arquemberg (French) Carburetor with Venturi Tube Mixing Chamber and Air Port Control by Floating Balls.

openings cut in it registering with the gas outlet and the orifice communicating with the mixing chamber. The gasoline supply is regulated by a needle valve which may be adjusted to regulate the size of the opening in the nozzle. The mixing chamber is water-jacketed, and as the stream of hot water from the engine is kept circulating through the water space the heat tends to promote more positive vaporization of fuel and insure thorough mixture of gasoline and air.

The Grouvelle and Arquemberg carburetor depicted at Fig. 152 is a foreign type that has been applied with some degree of success in this country. The float chamber is carried to one side of the mixing chamber and the usual Venturi tube construction is followed. No gasoline regulation is possible without changing the spraying nozzle, and as the auxiliary air supply is regulated by a series of ball valves this adjustment cannot be varied. The mixing chamber is water-jacketed and the amount of fuel admitted to the cylinders is regulated by a simple disk valve. It is advanced by the makers of this apparatus that once fitted to an engine it will need no further attention and is entirely automatic in its action. The combination of the Venturi tube and the floating ball auxiliary air control are said to provide mixtures of suitable proportions for all engine speeds without using adjustable members which are liable to get out of order and cause trouble.

Another simple form of carburetor in which the Venturi tube effect is depended upon is shown at Fig. 153. In this device the carburetor and induction pipe are a unit. The float chamber is carried to one side of the mixing chamber and the auxiliary air valve and throttle are located at the top of the air tube. The float chamber and spray nozzle construction are conventional, but the combined throttle and air valve construction is unique. The air valve is a light sheet metal member located at the extreme top of the mixing chamber and held to its seat by a cone-shaped helical spring. The air valve is guided by the throttle stem. The throttle consists of a cylindrical member connected to a hub by four ribs, and when it is desired to shut off the gas the lower portion of the throttle seats against the top of the air tube, thus effectively shutting off the branches which lead to the cylinder from the central member.

Owing to the small bore of the mixing chamber a rich gas is inspired at low motor speeds, and when the suction effect increases the auxiliary air supply enters through the throttle and meets the incoming column of rich gas to dilute it sufficiently to obtain a properly proportioned mixture. The course of the gas is direct, rising vertically from the top of the spray nozzle to the throttle where it branches to the two inlet pipes forming the letter Y.

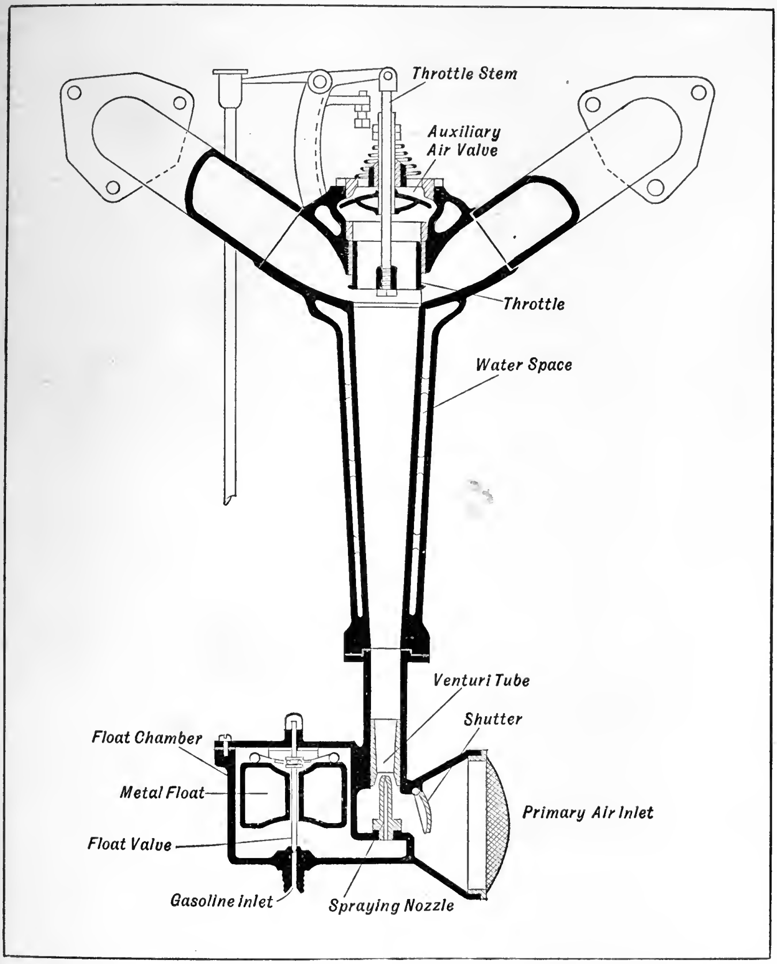


Fig. 153.—Peerless Carburetor, which is Combined with Induction Manifold. Has Spray Nozzle and Float Chamber at Bottom and Air Valve at Top.

The air tube is water-jacketed its full length to insure vaporization of comparatively low grade fuel. The main air entrance is through a funnel-shaped opening provided with a fine mesh screen, past a hinged shutter and then around the spray nozzle. The function of the shutter is to promote easy starting, as it may be dropped so the air pipe is almost shut off when it is desired to promote high gas velocity past the top of the spray nozzle. The mixture proportions are altered by changing the tension of the air valve spring which directly affects the degree of opening and the amount of auxiliary air inspired.

A simple form of automatic carburetor is shown at Fig. 154. This utilizes a concentric mixing chamber of the Venturi tube type. The auxiliary air port is controlled by a flat seat valve and the gasoline spray is regulated by an overhead needle adjusting tube. The air entrance through an air bend at the bottom of the carburetor flows past the spray nozzle and out through the gas outlet which is controlled by a butterfly throttle valve. A feature of this instrument is the detachable strangling tube which may be removed in case the proper adjustments cannot be obtained by the air valve and gasoline needle and replaced by one of larger or smaller bore as conditions demand.

Multiple Nozzle Vaporizers.—To secure properly proportioned mixtures some carburetor designers have evolved forms in which two or more nozzles are used in a common mixing chamber. The usual construction is to use two, one having a small opening and placed in a small air tube and used only for low speeds, the other being placed in a larger air tube and having a slightly augmented bore so that it is employed on intermediate speeds. At high speeds both jets would be used in series. Some multiple jet carburetors could be considered as a series of these instruments each one being designed for certain conditions of engine action. They would vary from small size just sufficient to run the engine at low speed to others having sufficient capacity to furnish gas for the highest possible engine speed when used in conjunction with the smaller members which have been brought into service progressively as the engine speed has been augmented. The multiple nozzle carburetor differs from that in which a single spray tube is used only in the construction of the mixing chamber, as a common float bowl can be used to supply all spray pipes. It is common practice to bring the jets into action progressively by some form of mechanical connection with the throttle or by automatic valves.

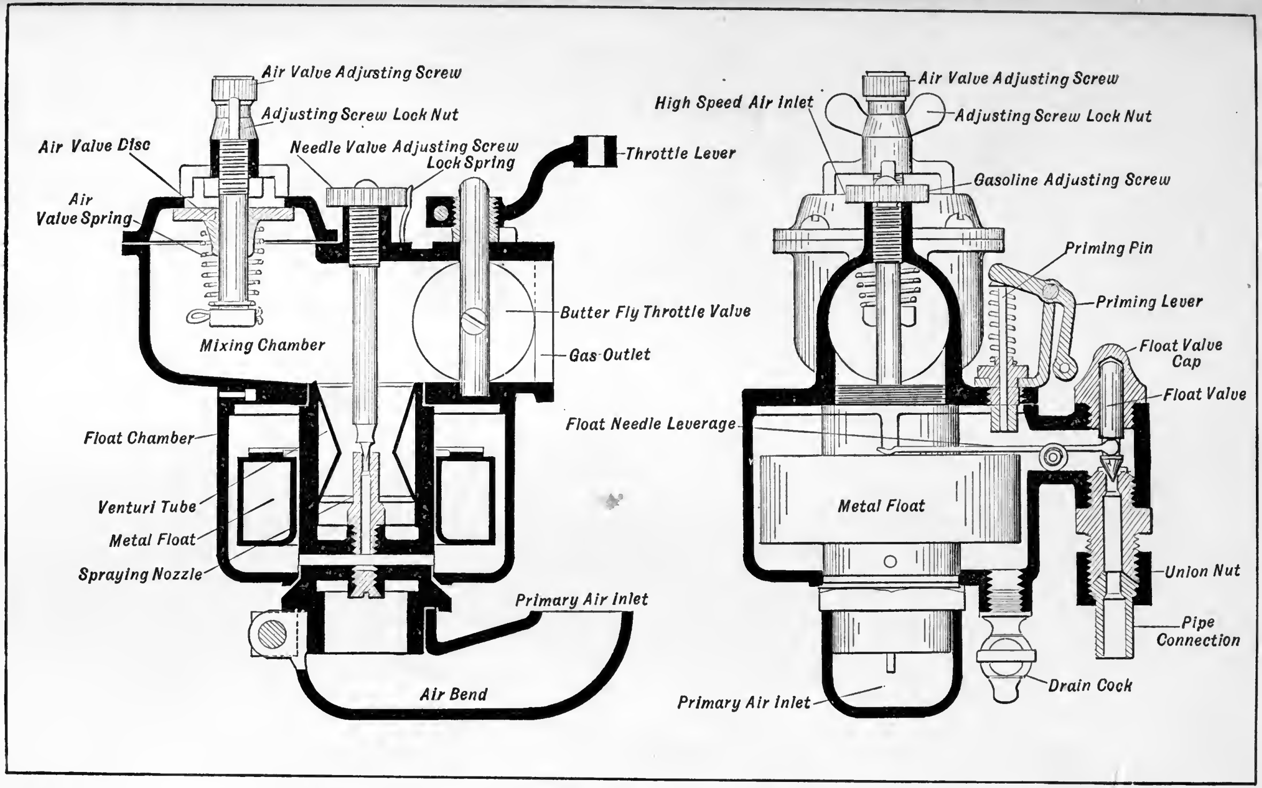


Fig. 154.—Showing Details of Breeze Carburetor, a Simple Automatic Instrument. Note Fuel-Adjustment Needle Valve Over Spray Nozzle.

A simple form of multiple jet carburetor i3 shown at **Fig. 155**, this being an adaptation of the Stromberg carburetor. It does not differ materially from the single jet construction except that there is

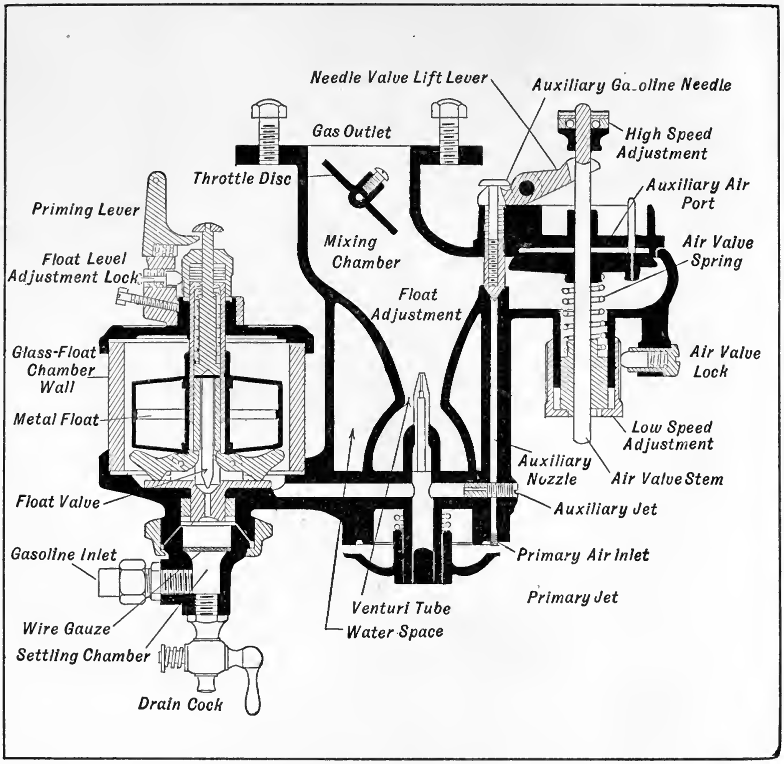


Fig. 155.—Details of Stromberg Double-Jet Carburetor, which Provides Extra Fuel Through Auxiliary Spray Jet when Motor Demands It.

an auxiliary nozzle which is closed by a spring-controlled auxiliary gasoline needle. This is operated by « needle valve lift lever which in turn is affected only when the auxiliary air valve is drawn down, a certain distance by the motor suction. At low and intermediate speeds the mixture is supplied through the primary jet in the main mixing chamber. When the engine speed augments to such an extent that the auxiliary air valve is opened to a certain point the adjusting nut on the end of the valve stem bears against the long arm of the lever and lifts the auxiliary gasoline needle from its seat. More gasoline is then sprayed into the mixture which has become too thin because of an oversupply of air through the auxiliary valve and proper mixture proportions are maintained.

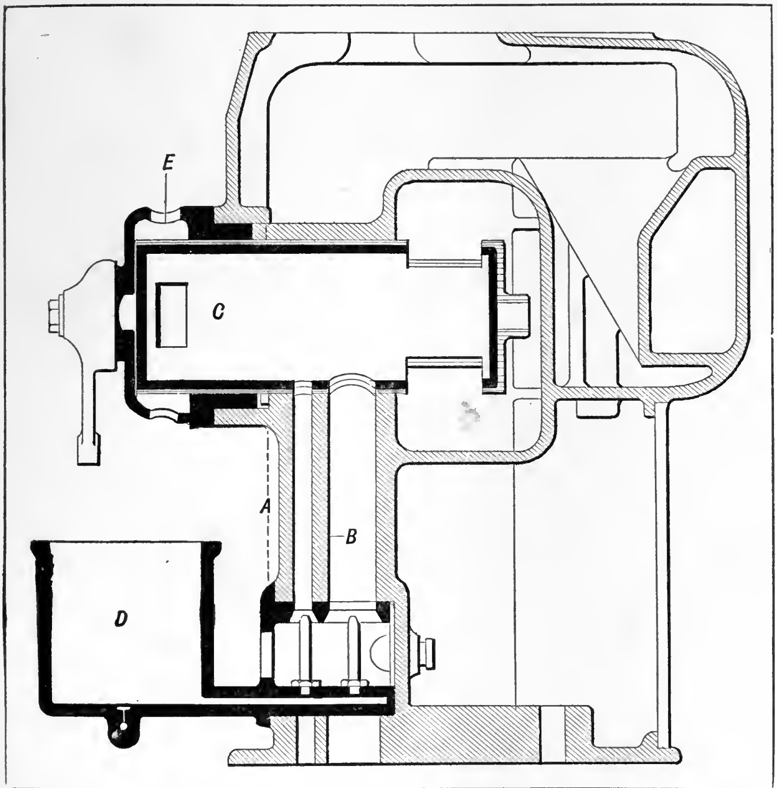


Fig. 156.—Carburetor Incorporated in F. I. A. T. Cylinder Casting Is a Multiple-Jet Type Having Two Spray Tubes.

The form shown at Fig. 156 is a novel one in several respects. It is the type where a common float bowl supplies both spray nozzles. The small nozzle A is used at low speeds and is brought into communication with the throttle chamber C by a small port in the throttle shell. When the throttle is opened still further to secure higher speed of the motor the mixing nozzle B, which is a larger one, is brought into play and assists the nozzle A, which would be inadequate if used alone. The auxiliary air enters through the openings E which are also controlled by ports in the throttle shell. One of the most distinctive features of this carburetor is the manner in which it is incorporated with the cylinder unit casting, it being installed at a point between the pairs of the cylinders. The induction manifold is formed integral with the cylinder casting and no outside manifold is used or needed. The throttle assembly is formed as a unit and inserted into a suitably machined opening while the float chamber and spray nozzle assembly is inserted at the lower portion as another unit.

A simple form of two-jet carburetor having an automatic control of the mixing chamber is shown in section at Fig. 157. In this a clack valve is used to close off the secondary mixing chamber at low speeds. All the air is drawn through a common opening and delivered to an annular air chamber which surrounds the mixing chamber. This permits one air inlet to serve both primary and secondary mixing chambers. At low throttle openings only the primary nozzle is utilized and the amount of gasoline supplied can be adjusted to a degree which will insure a mixture of such proportions as will produce steady running with minimum gasoline consumption.

When the throttle is opened to increase engine speed the degree of suction is increased and at a time that the primary nozzle is not adequate to supply a full charge of gas the clack valve opens automatically and the secondary nozzle is brought into play. The valve is joined to a piston which works in a dashpot by means of a crank and connecting rod in order that its movement will be gradual. The coil spring back of the dashpot piston tends to keep the valve closed until the higher degree of vacuum or suction causes the valve to open against the spring resistance. If the throttle were suddenly closed the tendency of the valve might be to close very rapidly and to prevent too rapid movement of this member the piston is moved against an air cushion at the bottom of the dashpot cylinder. As this member must oscillate to a certain extent when the shutter works back and forth it is journaled at its lower end to permit a certain degree of movement. As will be evident both spray nozzles furnish mixture at

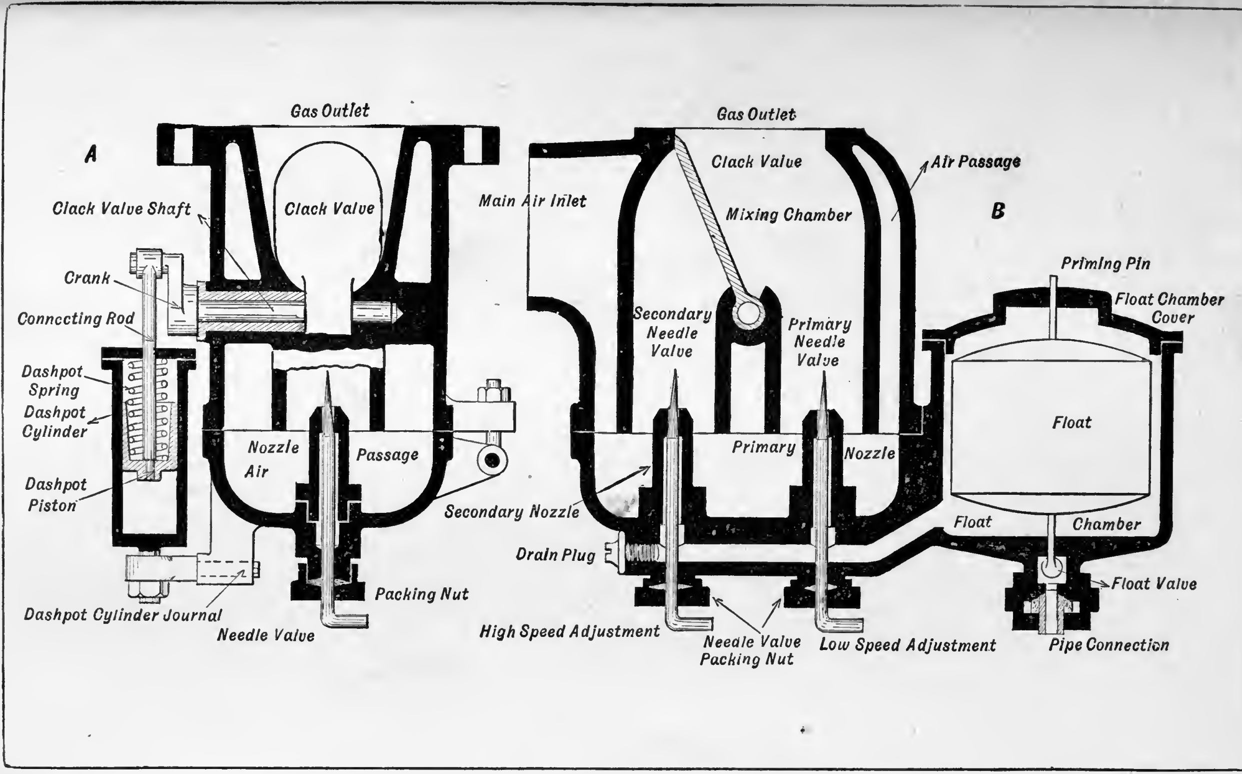


Fig. 157.—Defining Principles of Construction Incorporated in Saurer Economy Carburetor, a Two-Jet Form Having Automatic Control of Mixture.

high engine speeds. The view shown at A depicts clearly the construction of the clack valve and how its motion is controlled by the crank, connecting rod and piston in the dashpot cylinder. The view at B depicts clearly the arrangement of the float and mixing chambers, and the method of supplying both primary and secondary nozzles with air through one main air inlet and with gasoline from a common source.

In the Zenith carburetor, which is shown at Fig. 158, a compound nozzle is used, this being composed of two jets designated as G and H. The center nozzle G is the main member and concentric with it is a tube which forms the compensating jet H. The inner nozzle communicates with the float chamber through passages E and C, while the annular space between the main jet and the cap of the compensating member is supplied with gasoline by the passage F. At one side of the mixing chamber, and between that member and the float compartment, is a cylinder in which the secondary well P and the priming tube K are suspended. The upper end of the priming tube is in communication with the passage U in the mixing chamber walls. The passage U is controlled by the throttle T. When the throttle is closed the suction through the priming tube K is so great that it drains the gasoline from the secondary well and furnishes a very rich mixture through the opening U in the wall of the air tube D. The gasoline enters the secondary well P through the small hole Q at the bottom. With this vaporizer the quantity of air increases almost directly as the engine speed but the gasoline supply does not.

Since the air supply increases with a constant ratio the amount of gasoline must be regulated to such proportions that a correct mixture will be obtained at all speeds. This is the function performed by the double nozzle because at low speed the outer or compensating nozzle has a large quantity of fuel, but this decreases as the engine speed augments until at high speed the compensating nozzle does not add much fuel to the mixture. In this form the multiple nozzle construction is employed to do away with the automatic air valve, all air being drawn through the primary air opening at the bottom of the mixing tube D. A strangling tube A is dropped into the air tube in order to constrict its area at the spray nozzle and secure a Venturi tube effect.

The object of any multiple nozzle carburetor is to secure greater flexibility and endeavor to supply mixtures of proper proportions at all speeds of the engine. It should be stated, however, that while devices of this nature lend themselves readily to practical application

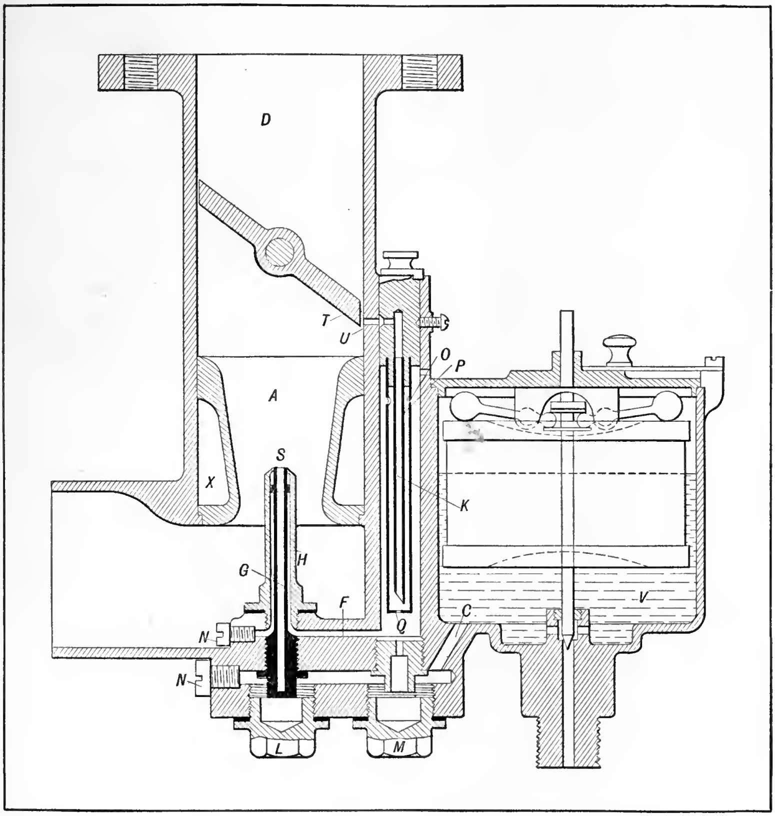


Fig. 158.—The Zenith Carburetor, which Embodies Novel Application of Double-Jet Principle, One Spray Nozzle Being Concentric with the Other.

it is more difficult to adjust them than the simpler forms, having but one nozzle. When a number of jets are used the liability of clogging up the carburetor is increased, and if one or more of the nozzles is choked by a particle of dirt or water the resulting mixture trouble is difficult to detect. One of the nozzles may supply enough gasoline to permit the engine to run well at certain speeds and yet not be adequate to supply the proper amount of gas under other conditions.

In adjusting a multiple jet carburetor in which the jets are provided with gasoline regulating needles, it is customary to consider each nozzle as a distinct carburetor and to regulate it to secure the best motor action at that throttle position which corresponds to the conditions under which the jet is brought into service. For instance, that supplied the primary mixing chamber should be regulated with the throttle partly closed, while the auxiliary jet should be adjusted with the throttle fully opened.

Utility of Gasoline Strainers.—Many carburetors include a filtering screen at the point where the liquid enters the float chamber in order to keep dirt or any other foreign matter which may be present in the fuel from entering the float chamber. This is not general practice, however, and the majority of vaporizers do not include a filter in their construction. It is very desirable that the dirt should be kept out of the carburetor because it may get under the float control fuel valve and cause flooding by keeping it raised from its seat. If it finds its way into the spray nozzle it may block the opening so that no gasoline will issue or may so constrict the passage that only very small quantities of fuel will be supplied the mixture. Where the carburetor itself is not provided with a filtering screen a simple filter is usually installed in the pipe line between the gasoline tank and the float chamber.

Some simple forms of filters and separators are shown at Fig. 159. That at A consists of a simple brass casting having a readily detachable gauze screen and a settling chamber of sufficient capacity to allow the foreign matter to settle to the bottom from which it is drained out by a pet cock. Any water or dirt in the gasoline will settle to the bottom of the chamber, and as all fuel delivered to the carburetor must pass through the wire gauze screen it is not likely to contain impurities when it reaches the float chamber. The heavier particles, such as scale from the tank or dirt and even water, all of which have greater weight than the gasoline, will sink to the bottom of the chamber, whereas light particles, such as lint, will be prevented from flowing into the carburetor by the filtering screen.

The filtering device shown at B is a larger appliance than that shown at A, and should be more efficient as a separator because the gasoline is forced to pass through three filtering screens before it reaches the carburetor. The gasoline enters the device shown at C

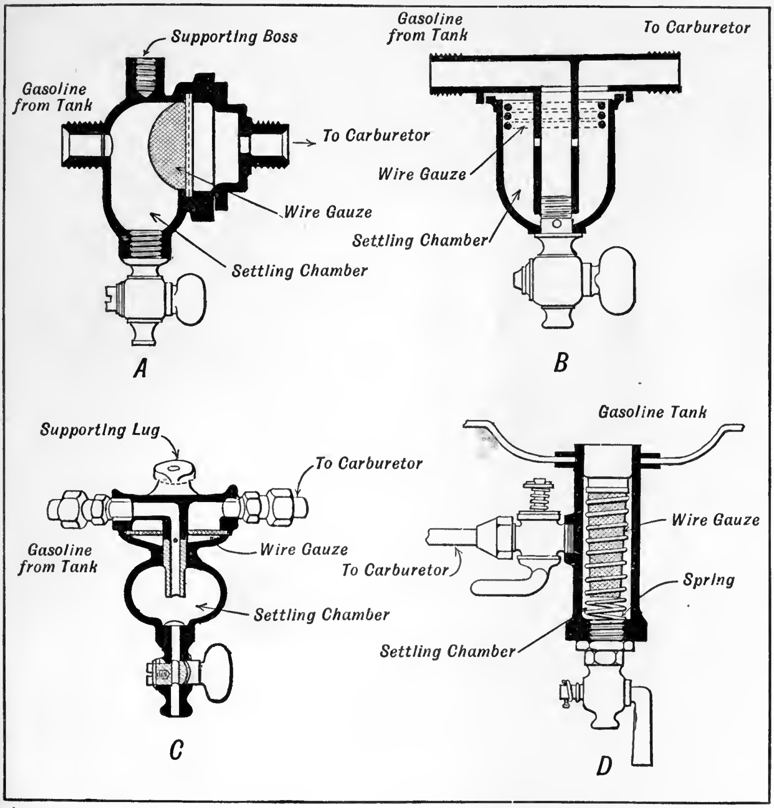


Fig. 159.—Types of Strainers Interposed Between Vaporizer and Gasoline Tank to Prevent Water or Dirt Passing Into Carbureting Device.

through a bent pipe which leads directly to the settling chamber and from thence through a wire gauze screen to the upper compartment which leads to the carburetor. The device shown at D is used on Chalmers motor cars and is a combination strainer, drain, and sediment cup. The filtering screen is held in place by a spring and both are removed by taking out a plug at the bottom of the device. The shut-off valve at the top of the device is interposed between the sediment cup and the carburetor. This separating device is incorporated with the gasoline tank and forms an integral part of the gasoline supply system. The other types shown are designed to be interposed between the gasoline tank and the carburetor at any point in the pipe line where they may be conveniently placed.

How Kerosene May be Utilized.—The carburetion of kerosene seems to be partially solved at the present time, and there are several forms of carbureting devices which permit one to utilize this fuel. It is important that the vaporizer employed be one that can be readily adapted to present day forms of motors. It is a fact that with lower grade fuels, as kerosene or benzol, a motor of lower compression than one can use successfully with gasoline and some means for heating the entering mixture are needed. When kerosene is used as fuel the conditions are similar to those which obtain with gasoline except the temperature at which vaporization commences. The heavier liquid requires more heat to cause it to vaporize, it being necessary to preheat kerosene to about two hundred degrees Fahrenheit before it will evaporate and form a mixture with air. It is necessary to provide a heated passage to further vaporize the mixture as it leaves the spray nozzle and as direct an entrance to the motor should be provided as possible. It is necessary to maintain a high velocity of the kerosene vapor in order to prevent condensation.

The carburetor depicted at Fig. 160 is the Holley form adapted to use kerosene. It consists of a conventional form concentric jet, float-feed vaporizer, to which the kerosene is fed at the lower end and a mixing chamber having an auxiliary air valve is carried at the upper end of the device. In connection with this appliance a simple form of gasoline vaporizing valve is mounted at the upper end near the gas outlet, and is used to supply mixture enough to promote easy starting of the motor. The exhaust gases from the motor are passed through a jacket which surrounds the mixture tube leading from the kerosene vaporizer and which goes through the float bowl to heat the fuel therein.

The liquid in the fuel container is heated to about two hundred degrees before it is sprayed in the motor, and it is contended that if kerosene is kept near its boiling point it will leave the spray nozzle just as readily as gasoline will at ordinary temperature. It would be extremely difficult to start an engine on kerosene unless the vaporiz-

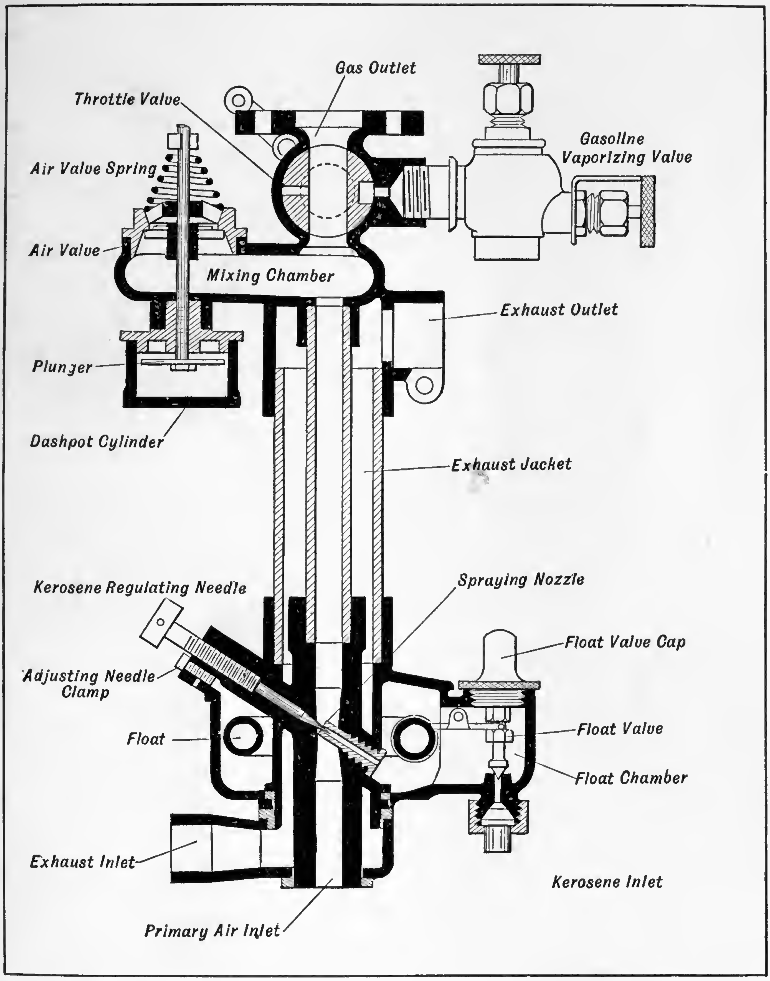


Fig. 160.—Holley Combined Gasoline and Kerosene Carburetor. May Be Used with Either Fuel, Though Specially Adapted for the Less Volatile Liquid Distillates of Petroleum, Because of Preheating Arrangement.

ing device was raised in temperature to a point that would permit of ready vaporization of fuel. In the device shown at Fig. 160 if the motor is to be started cold the mixture supplied by the gasoline vaporizing valve is directed into the cylinder by a three-way valve which closes off the kerosene compartment and provides a by-pass for the gasoline mixture through the gas outlet. After the engine has run for a time, usually two or three minutes, the kerosene vaporizer has been raised in temperature to the proper point and a shift from one fuel to another is easily made by throwing the three-way valve over so that the gasoline vaporizer is shut off from the gas outlet and direct communication is provided by the large opening in the throttle valve between the motor cylinder and the mixing chamber of the kerosene carburetor.

When kerosene vapor is used with the usual type of induction manifold it is liable to condense if conditions are unfavorable to rapid

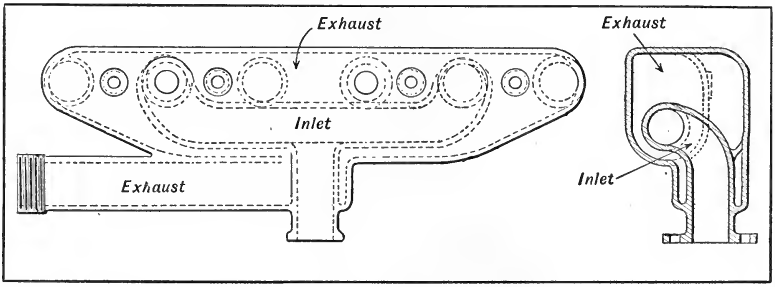


Fig. 161.—Combined Intake and Exhaust Manifold Suggested as Suitable for Use with Kerosene and Air Mixture. The Hot Exhaust Gases Heat the Inlet Pipe Walls and Produce More Complete Vaporization.

volatilization. This "loading up" as it is called is due to the low velocity and temperature of the mixture which passes through comparatively large passages, and while it can be reduced to a certain extent by making the area of the manifold cross section smaller, this is not desirable because at high speeds it would not be possible to supply an adequate amount of mixture to the cylinders unless the full cross section of the intake pipe is used. To minimize condensation the combination manifold shown at Fig. 161 has been recommended. This consists of forming the intake and exhaust manifold in one casting, the thought being to heat the inlet manifold by the hot inert products of combustion to such a point that the kerosene vapor would be turned into a gas and all liquid particles vaporized. It is recommended that a manifold of this type be used in connection with the carburetor shown at Fig. 160.

It is stated that the heated vapor from the kerosene vaporizer with its quota of air comprises about one fourth of the total volume of the charge, the balance of the air being supplied by the auxiliary valve at the top of the kerosene vaporizer. When the proper degree of compression obtains in the motor and the kerosene is properly heated before attempt is made to vaporize it the action of the carburetor described is claimed to be very similar to that of a gasoline vaporizer. It is claimed that it is possible to convert the usual gasoline motor by adding a spacer of proper thickness under the cylinder to reduce the compression to the point where kerosene can be used successfully. The degree of compression recommended as most suitable for use with kerosene vapor furnished by a carbureting device is between fifty and sixty pounds per square inch.

Another important consideration is that the initial heating of the motor parts by use of gasoline gas be complete before one attempts to use kerosene. If the heavier liquid is supplied to the engine before the carburetor has been raised to the proper degree of temperature, poor combustion of kerosene results and carbon deposits, or gummy residue is deposited in the interior of the combustion chamber.

Supplying Kerosene by Direct Injection.—The most logical method of utilizing fuels which have a low vaporizing point and which must be raised in temperature before they will give off vapor is to supply to the motor cylinder by direct injection. Several types of stationary power plants and some used in marine applications have been designed to use the cheaper fuels which cost less than gasoline, such as kerosene, benzol, or crude oil. The view at Fig. 162 is a section through a Detroit two-port two-cycle engine which has been adapted to use kerosene by direct injection. The engine is of the conventional pattern, having an automatic inlet valve at the side of the crank case to admit air on the upward stroke of the piston. If this engine was used with gasoline the carburetor or mixing valve would be attached to this check valve cage and the engine would operate on the two-port principle.

In the design under discussion the fuel supply device consists of a float feed arrangement attached to a spray nozzle placed in the transfer port in such a way that it discharges the fuel against the deflector

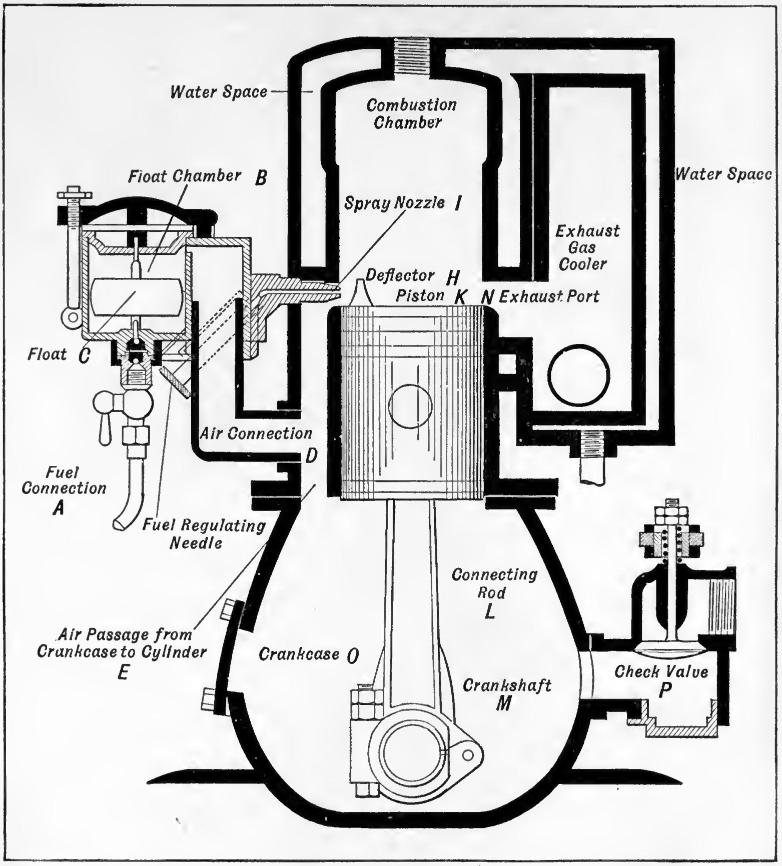


Fig. 162.—Showing Two-Cycle Motor with Device for Direct Injection of Heavier Petroleum Distillates into Cylinder.

plate on the piston top. The float keeps the kerosene level in the float chamber to a height equal to the point of the spray jet. The amount of kerosene supplied can be regulated by the usual needle valve which controls the nozzle opening.

Assume for the purpose of making the explanation clearer that the cylinder is full of fresh gas and that the piston is traveling upward. It will close the transfer passage and the exhaust port and will compress the charge above it. As the piston continues to move upward a vacuum is created in the crank case O which draws in a current of air through the spring-controlled automatic valve P, and fuel into the fuel-feeding chamber. At the top of the compression stroke the gas is ignited by an electric spark and the resulting explosion causes a downward movement of the piston. As this member moves toward the end of its stroke the air in the crank case and the fuel-supply chamber is under compression. As the exhaust port is uncovered by the piston as it continues to go down the inert products of combustion, which have a pressure of forty to fifty pounds per square inch, stream out of the open port until but a very small portion of burned gas which is at atmospheric pressure remains at the cylinder.

As the piston continues to move down it uncovers the spraying nozzle I. The compressed air in the crank case rushes into the cylinder F and strikes the deflector H which directs it to the top of the cylinder and drives before it the remainder of the burned gases out of the open exhaust port. Simultaneously with this function the pressure in the fuel chamber B relieves itself by spraying a stream of fuel through the nozzle I. As this stream of liquid strikes the hot deflector plate it is immediately vaporized, and as it is in the center of the incoming air stream it mixes with it to form an inflammable mixture.

A disadvantage of this method of fuel injection is that it does not provide for the flexibility of engine action which is so essential in automobile service. This disadvantage does not militate against it to any great extent in stationary or marine application where the motor speed does not need to be varied within a wide range and where constant speeds are more often used. This method of automatic fuel injection is not practical when a four-cycle engine is used, and if fuel is to be suppled in this manner a small plunger pump driven by the engine is usually employed to force it into the combustion chamber under considerable pressure.

Intake Manifold Design and Construction.—On four- and six-cylinder engines and in fact on all multiple-cylinder forms, it is important that the piping leading from the carburetor to the cylinders be made in such a way that the various cylinders will receive their full quota of gas and that each cylinder will receive its charge at about the same point in the cycle of operations. In order to make the passages direct the bends should be as few as possible, and when curves are necessary they should be of large radius because an abrupt corner will not only impede gas flow but will tend to promote condensation of the fuel. Every precaution should be taken with four- and six-cylinder engines to insure equitable gas distribution to the valve chambers if regular action of the power plant is desired. If the gas pipe has many turns and angles it will be difficult to charge all cylinders properly.

The problem of intake piping is simplified to some extent on block motors where the intake passage is cored in the cylinder casting and where but one short pipe is needed to join this passage to the carburetor. If the cylinders are cast in pairs a simple pipe of T or Y form can be used with success. When the engine is of a type using individual cylinder castings, especially in the six-cylinder power plants, the proper application and installation of suitable piping is a difficult problem.

Intake piping is constructed in two ways, the most common method being to cast the manifold of brass or aluminum. The other method, which is more costly, is to use a built-up construction of copper or brass tubing with cast metal elbows and Y pieces. One of the disadvantages advanced against the cast manifold is that blowholes may exist which produce imperfect castings and which will cause mixture troubles because the entering gas from the carburetor, which may be of proper proportions, is diluted by the excess air which leaks in through the porous casting. Another factor of some moment is that the roughness of the walls have a certain amount of friction which tends to reduce the velocity of the gases, and when projecting pieces are present, such as core wire or other points of metal, these tend to collect the drops of liquid fuel and thus promote condensation.

The advantage of the built-up construction is that the walls of the tubing are very smooth, and as the castings are small it is not difficult to clean them out thoroughly before they are incorporated in the manifold. The tubing and castings are joined together by hard soldering or brazing, and extreme care is needed to insure tight joints at all points.

Some typical manifolds used on four-cylinder engines of various types are depicted at Fig. 163. That at A is composed of four pipes leading from a central member, each one communicating with an

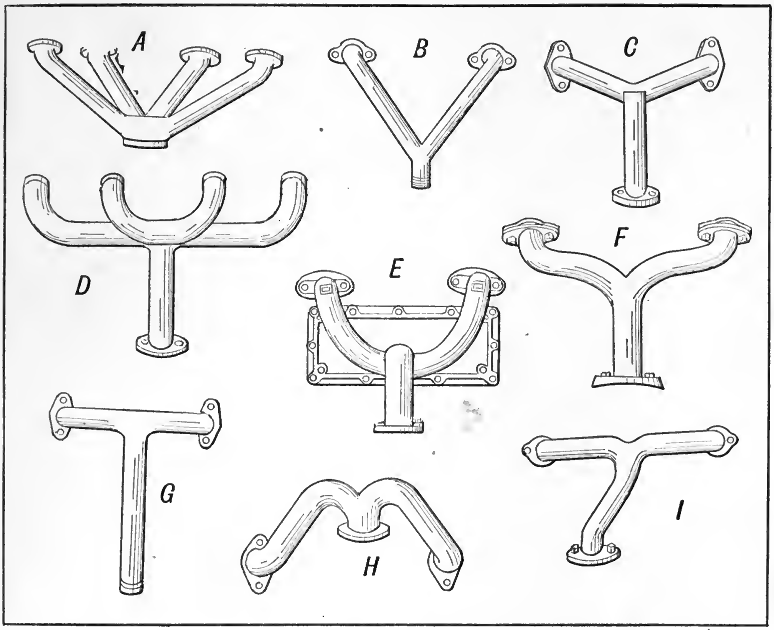


Fig. 163.—Typical Induction Pipes Used on Four-Cylinder Motors.

individual cylinder. The pipes are so nearly the same length that gas distribution is fairly uniform. The manifolds shown at B and C are substantially the same, except that one is a more pronounced Y than the other. Both are cast forms, that at B being of round section, while that at C is a square section casting. The manifold depicted at D is another type which has been evolved for use with a four-cylinder motor having individual cylinder castings.

At E a cast manifold which is combined with a water-jacket cover plate used on the Chalmers block motor is illustrated, it being plain that the heating effect of the jacket-water tends to raise the temperature of the entire manifold and promote more rapid vaporization if low-grade fuels are used. The manifold at F is a type applied to a four-cylinder motor having cylinders cast in pairs, and this cast form has been made with graceful curves rather than straight lines. The induction pipe depicted at G is also utilized to supply a four-cylinder motor having twin cylinder castings and is made in the form of a letter T. At H a ramshorn type is outlined, the curves being reversed to the usual construction. The form at I is still another variation of the simple two-branch or T form of induction pipe.

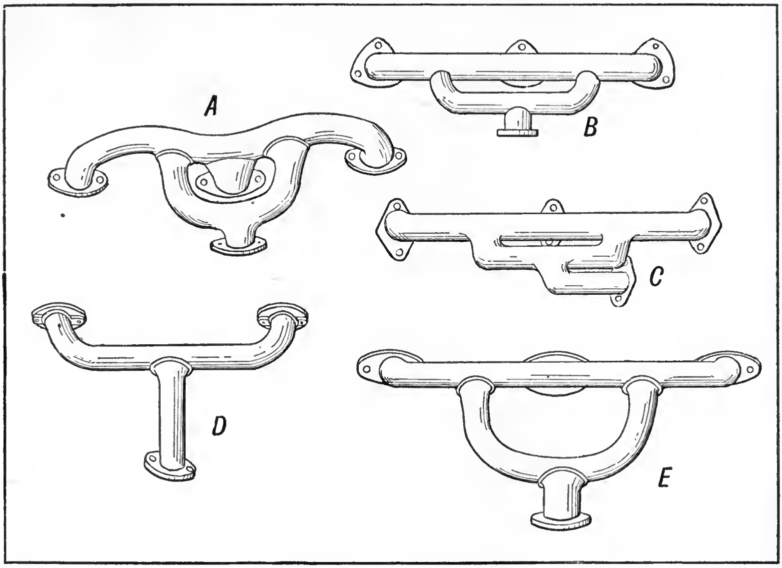


Fig. 164.—Conventional Inlet Manifolds Adapted for Six-Cylinder Motors.

When six-cylinder motors are used the problem is one that is not so easily solved, and designers show considerable ingenuity in devising manifolds to secure even charge distribution. A number of conventional forms that have received successful application are depicted at Fig. 164. All types shown except that outlined at D are used with six-cylinder engines having three pairs of cylinders, while that at D is employed when the motor is composed of two three-cylinder block castings. All the manifolds illustrated are built-up forms composed of tubing and cast fittings with the exception of that outlined at C, which is a cast aluminum member.

Another group of six-cylinder manifolds is given at Fig. 165. The forms at A, B, C, and E are designed for use with six-cylinder motors

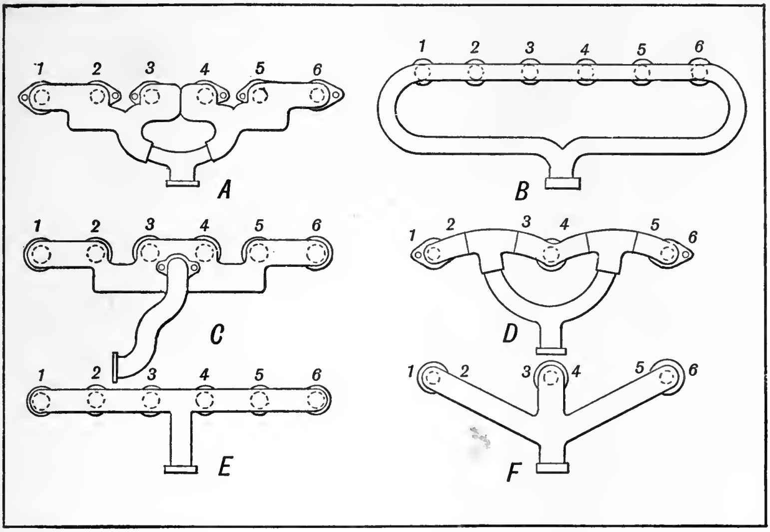


Fig. 165.—Some Unconventional Forms of Gas Supply Pipes Used On Six-Cylinder Power Plants.

having individual cylinder castings. The form at A, while of peculiar shape, provides gas passages of about the same length leading to all cylinders. This is not true of those shown at B, C, and E, which are faulty in design, inasmuch as the gas will reach cylinders three and four much quicker than it will get to two and five, and to these two cylinders quicker than it will reach those on the extreme ends of the manifold, or one and six. It is claimed that the loop shown at B has given very satisfactory results, and that the peculiar construction compensates to a certain degree for the varying lengths of piping leading from the carburetor to the various valve chambers. The manifold at D is a built-up form utilized when cylinders are cast in pairs, and is much superior to that outlined at F, which is a cast aluminum member designed for the same type of motor.

Compensating for Varying Atmospheric Conditions.—The low-grade gasoline used at the present time makes it necessary to use vaporizers that are more susceptible to atmospheric variations than when higher grade and more volatile liquids are vaporized. Sudden temperature changes, sometimes being as much as forty degrees rise or fall in twelve hours, affect the mixture proportions to some extent, and not only changes in temperature but variations in altitude also have a bearing on mixture proportions by affecting both gasoline and air. As the temperature falls the specific gravity of the gasoline increases and it becomes heavier, this producing difficulty in vaporizing. The tendency of very cold air is to condense gasoline instead of vaporizing it and therefore it is necessary to supply heated air to some carburetors to obtain proper mixtures during cold weather. In order that the gas mixtures will ignite properly the fuel must be vaporized and thoroughly mixed with the entering air either by heat or high velocity of the gases.

As it would be somewhat inconvenient to constantly regulate the average carburetor from day to day by the regular adjustments incorporated in the device, forms of dash-controlled regulators have been devised. One of these is shown at Fig. 166 as applied to the Holley carburetor. It consists of a special form of valve interposed between the hot air connection around the exhaust manifold and the primary air entrance at the side of the carburetor. It is worked by a simple key and leverage connection. An indicator plate on the dash shows the different positions of the regulator. When the shutter is in the position shown at A only cold air is supplied the carburetor, this being the proper position for summer running. When in the position shown at B the cold air slot is closed and only warm air which is taken from the jacket surrounding the exhaust pipe is supplied the carburetor. This would be the proper position for cold or damp weather. If the shutter is placed as shown at C the air supplied the carburetor will be composed of both warm and cold currents in any desired proportion. When it is desired to exert a strong suction on the gasoline in the carburetor, as is often necessary in starting, the shutter may be turned as depicted at D in which case both air openings are shut off with the exception of but a very small slot. The equipment illustrated has been designed especially for use with the

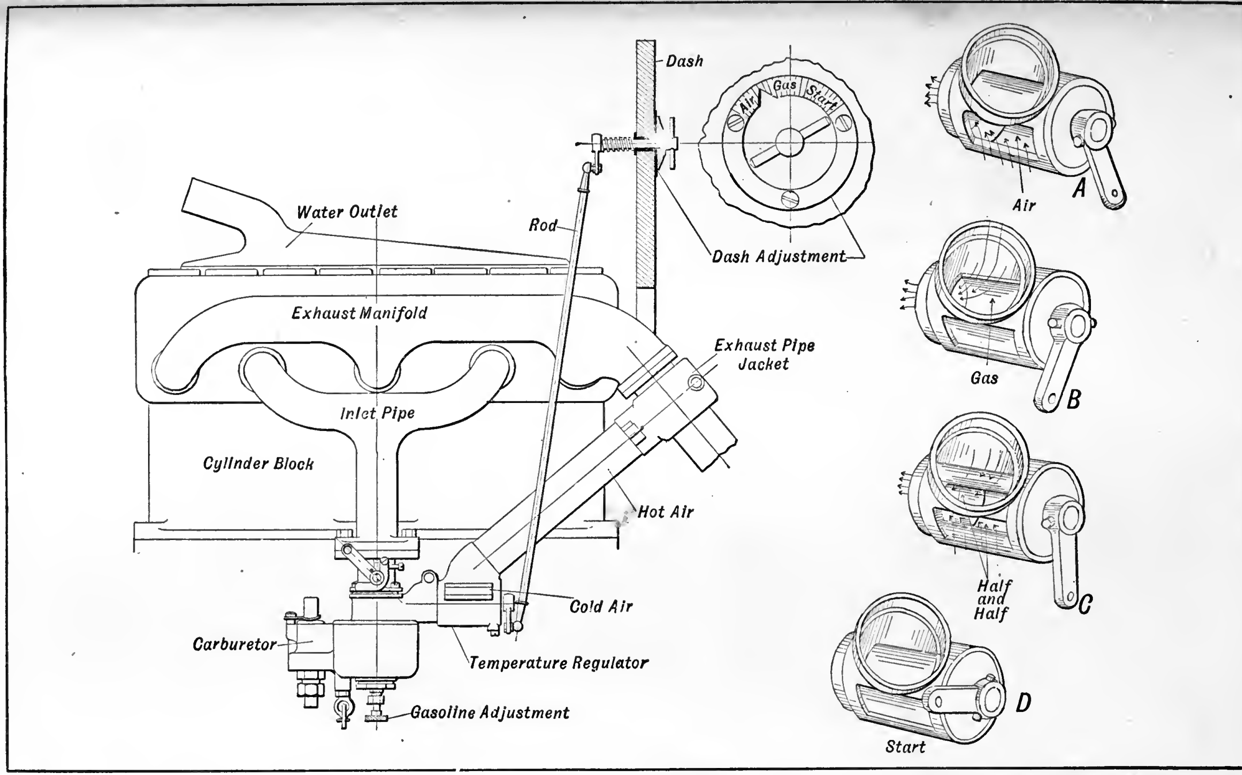


Fig. 166.—Holley Method of Compensating for Temperature Variations and Securing Easy Starting from Dash-Adjusted Regulator. Positions of Regulator Valve Sleeve for Different Conditions Outlined.

Holley carburetor and is supplied by the manufacturers of that device. Air shutter regulation has been used on many cars, however, and has proved to be a very satisfactory way of compensating for extremes of temperature or altitude and variations in fuel quality.

Disposition of Exhaust Gases.—While the problem of getting the fresh gases into the cylinders is an important one the means of disposing of them after they have been burned is also important. The form of the exhaust manifold, which is usually a large malleable iron casting, is not so important as that of the induction pipe and the chief precaution to be observed is to make the passages in this member as large as possible and to proportion it in such a way that all parts of the casting will expand with the same ratio. An important condition to be observed, however, is the method of discharging the gases to the air and for this purpose various forms of mufflers, or silencers, are used so that the gases will be discharged in an unobjectionable manner.

It has been demonstrated that the average motor vehicle engine cannot utilize the full expansive force of the burned charge because the exhaust valve is opened a certain number of degrees before the bottom center or before the piston reaches the end of its power stroke. This is done to give a lead or start to the gases and obtain higher engine speeds than would otherwise be possible. As a result of the early opening of the exhaust valve the gases will issue through the valve port at sufficient pressure to produce a report like a gun shot which would be apt to disturb persons and animals of nervous temperament and at the same time not be exactly music to the normal ear.

It is not difficult to muffle the gases so there will be but little noise to the exhaust, but it is quite a problem to do it without producing back pressure in the muffling device that will cause serious loss of power. A muffler should offer minimum resistance to the passage of the gas and means should be provided for not only breaking the entering gas stream into smaller streams, but the capacity of the muffler should be sufficiently large so that the gases will expand to nearly atmospheric pressure before they are discharged into the air.

Various forms of mufflers are shown in section at Fig. 167. The simplest, outlined at A, consists of a sheet metal shell having its ends closed by cast metal pieces. This has several times the volume of

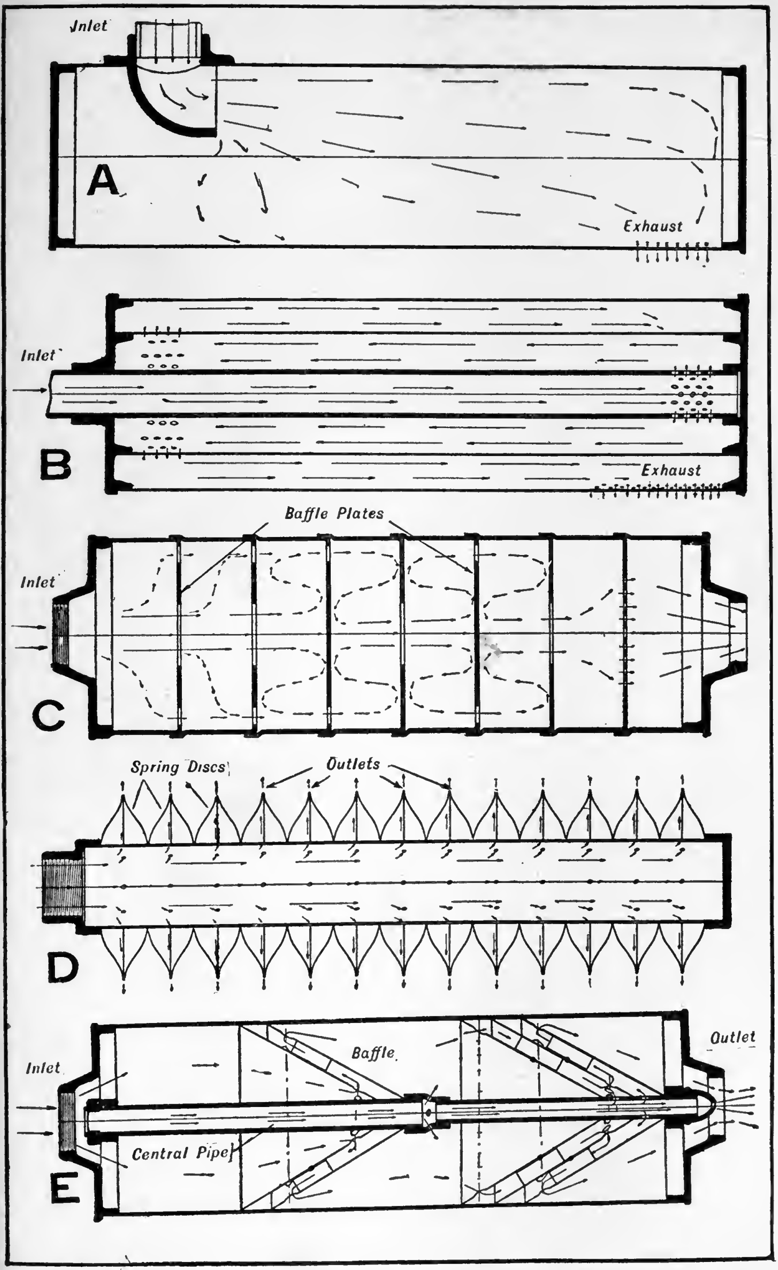


Fig. 167.—Muffler Forms Adapted to Reduce Pressure of Exhaust Gases Before Discharging Them.

the cylinder and the gases expand to about atmospheric pressure before they are discharged through the series of small holes at the bottom. The gas enters and leaves the muffler in streams indicated by the arrows. The objection to the use of small holes for breaking up the gas stream is that these are liable to clog with carbonaceous matter from the interior of the engine, such as would result when excessive amounts of oil were used or from mud or clay from the road surface.

The form shown at B consists of a number of concentric chambers which afford an excellent opportunity for the gas to expand to atmospheric pressure and to break it up thoroughly before it is discharged to the air. The exhaust gas enters the central pipe, passes out through a series of fairly large holes at its extremity into the middle compartment where it expands and passes out through another series of holes into the outer chamber. Here it again expands and finally leaves the muffler through a series of openings punched in the outer shell. The course of the gas may be easily followed by referring to the illustration, as it is indicated by arrows. A form employing a series of perforated baffle plates which divide the muffler body into eight compartments is shown at C. The function of the baffles is to break up the gas by making the gas streams follow a devious path through the first six chambers and expand into the seventh compartment, from which it passes to the eighth compartment through a series of fine holes in the last baffle plate of the series.

The form at D consists of a central pipe member around which are placed thirteen pairs of stamped disks which form the same number of expansion chambers. The gas issues from the center pipe, where opportunity is given it to expand into the chambers provided by the disks which are merely placed in contact with each other at their edges and held together by moderate pressure. The force of the gas causes the disks to spring slightly at their edges and thus produce an annular discharge passage in each set of disks which insures thorough breaking up of the issuing gas stream. It is claimed that this method of construction provides a large amount of cooling surface and that the pressure of the gas is reduced just as much by the cooling effect as it is by the increase in volume permitted by the expansion chambers.

The form shown at E is built on the ejector principle and is claimed to be particularly efficient, not only as relates to silencing qualities but also because back pressure is practically eliminated. The efficiency is due to its design, which allows that part of the gases which pass through the central pipe to do so with considerable force. This tends to produce a partial vacuum, which in turn promotes a ready expulsion of gas by drawing the main portion through the muffler rather than depend upon the upward stroke of the piston to clear both cylinder and muffler. This device is of the baffle plate type and the partitions are in the form of cones instead of the usual vertical or horizontal dividing walls because the conical form lends itself to the ejector principle better than the other types.

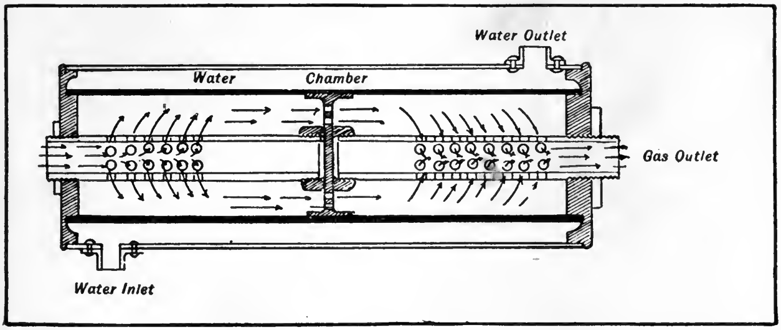


Fig. 168.—Water-Cooled Muffler Used when Exceptional Silence is Desired. Often Applied in Marine Service.

A very good muffler for marine purposes is shown at Fig. 168. This consists of a double-expansion chamber and a water jacket. If the exhaust gases are cooled they will be considerably reduced in volume and pressure and for this reason water cooled forms are very quiet. As the gases are considerably reduced in pressure by the cooling effect one may use large holes for the passage of gas from one chamber to the other and the back pressure is correspondingly reduced. While a water cooled form of muffler can be readily adapted to marine service, it is not possible to use such on a motor car because of the large volumes of water which would have to be supplied to insure adequate cooling of the muffling device.

It is sometimes possible to secure a more prompt discharge of the exhaust gases from the cylinder if a little attention is paid to the design of the exhaust manifold. The form shown at Fig. 169 is a com-

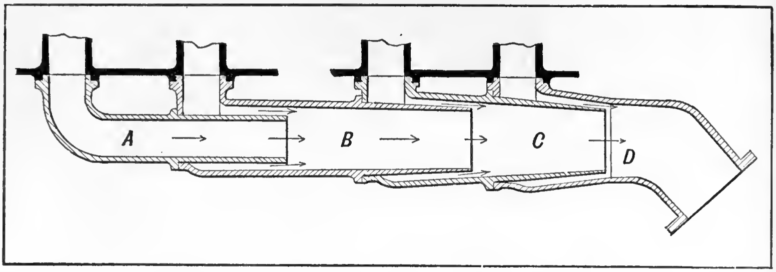


Fig. 169.—Suggested Exhaust Manifold in which Ejector Action of Exhaust Gases under High Velocity is Said to Reduce Back Pressure on Pistons.

posite member consisting of four separate castings, the object of the arrangement being to secure an ejector effect by which the discharge from any one cylinder would tend to keep a condition of partial vacuum in the manifold and thus draw out the gases. The discharge from cylinder 1 goes through pipe A; that from cylinder 2, through member B, while the gases from cylinders 3 and 4 pass out through pipes C and D respectively. If the exhausts occur in the order 1, 2, 4, 3, it will be seen that the gases flowing through pipe A will produce a certain suction effect in pipe B, which will tend to draw out the gases discharged from that cylinder when the exhaust valve opens. A manifold so constructed is but little more complicated than the ordinary construction, as it consists of the four bent tubes A, B, C and D, which are assembled together in such a manner that a portion of one projects into the other. The faster the engine works the more rapid the ejection of the gases and consequently the ejector action has a higher value at a time that it is needed the most. Such a manifold would be more expensive than the conventional pattern, however, and there might be some difficulty in keeping it tight at the multiplicity of joints.

Utility of Cut-out Valve Explained.—In order to take advantage of the gain in power which results when the gases are discharged directly into the air instead of being passed through the muffling device, many automobile makers provide a simple valve, which is called a "cut-out," between the exhaust manifold and the muffler. This is arranged in such a manner that when opened, the gases are free to issue directly to the air instead of passing through the muffling device, and as the back pressure incidental to the silencer is eliminated more power is obtained from the motor. A cut-out is also useful because it permits one familiar with gasoline motors to detect irregularity in engine operation by sound of the exhaust.

A typical cut-out installation is shown at Fig. 170, this being more efficient than that commonly used because even with the cut-out valve

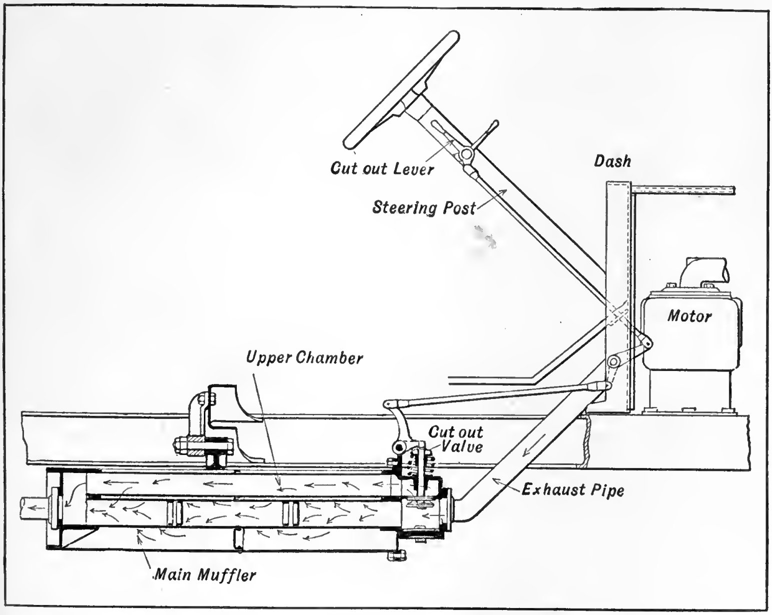


Fig. 170.—How Muffler Cut-out Valve is Arranged on Wolseley (English) Cars to Reduce Noisy Direct Exhaust.

opened the gases are silenced to a certain extent by being passed through the chamber P before they issue to the air. When the cut-out valve is closed the gases must follow a circuitous route through the muffler and by being broken up and allowed to expand issue to the air without appreciable noise. Whenever a cut-out valve is provided it is usually planned to open out so that any explosion of gas in the muffler which might result if the motor missed several explosions and then fired the gas in the silencer will tend to open the valve and relieve the excessive pressure in the muffling device. If some means were not provided to relieve the pressure, it might burst the muffler asunder. The average cut-out valve, therefore, performs three useful functions: First, it permits the exhaust gases to be discharged directly to the air at such times that maximum motor power is desired; second, it provides audible indication of irregular engine action; third, it is a safety or relief valve to prevent excessive pressures from damaging the muffler.

CHAPTER VI

Automobile Power Plant Ignition Systems Outlined—Chemical Current Producers—Mechanical Generators of Electricity—Essentials of Battery Ignition Systems—Functions of Timers and Distributors—Operating Principles of Induction Coil—Spark Plug Construction and Action Defined—Advantages of Two-Spark Ignition—Typical Battery Ignition Groups—Low-tension Ignition Systems—High-tension Magneto Forms—Typical Double Ignition Systems.

ONE of the most important auxiliary groups of the gasoline engine comprising the automobile power plant and one absolutely necessary to insure engine action is the ignition system or the method employed of kindling the compressed gas in the cylinder to produce an explosion and useful power. The ignition system has been fully as well developed as other parts of the automobile, and at the present time practically all ignition systems follow principles which have become standard through wide acceptance.

During the early stages of development of the automobile various methods of exploding the charge of combustible gas in the cylinder were employed. On some of the earliest engines a flame burned close to the cylinder head and at the proper time for ignition, a slide or valve moved to provide an opening which permitted the flame to ignite the gas back of the piston. This system was practical only on the primitive form of gas engines in which the charge was not compressed before ignition. Later, when it was found desirable to compress the gas a certain degree before exploding it, an incandescent platinum tube in the combustion chamber, which was kept in a heated condition by a flame burning in it, exploded the gas. The naked flame was not suitable in this application because when the slide was opened to provide communication between the flame and the gas the compressed charge escaped from the cylinder with enough pressure to blow out the flame at times and thus cause irregular ignition. When the flame was housed in a platinum tube it was protected from the direct action of the gas, and as long as the tube was maintained at the proper point of incandescence regular ignition was obtained.

Some engineers utilized the property of gases firing themselves if compressed to a sufficient degree, while others depended upon the heat stored in the cylinder head to fire the highly compressed gas. None of these methods were practical in their application to motor car engines because they did not permit flexible engine action which is so desirable. At the present time, electrical ignition systems in which the compressed gas is exploded by the heating value of the minute electric arc or spark in the cylinder are standard, and the general practice seems to be toward the use of mechanical producers of electricity rather than chemical batteries.

Two general forms of electrical ignition systems may be used, the most popular being that in which a current of electricity under high tension is made to leap a gap or air space between the points of the sparking plug screwed into the cylinder. The other form, which has been almost entirely abandoned in automobile practice, but which is still used to some extent on marine engines, is called the low-tension system because current of low voltage is used and the spark is produced by moving electrodes in the combustion chamber.

The essential elements of any electrical ignition system, either high or low tension, are: First, a simple and practical method of current production; second, suitable timing apparatus to cause the spark to occur at the right point in the cycle of engine action; third, suitable wiring and other apparatus to convey the current produced by the generator to the sparking member in the cylinder.

The various appliances necessary to secure prompt ignition of the compressed gases should be described in some detail because of the importance of the ignition system. It is patent that the scope of a work of this character does not permit one to go fully into the theory and principles of operation of all appliances which may be used in connection with gasoline motor ignition, but at the same time it is important that the elementary principles be considered to some extent in order that the reader should have a proper understanding of the very essential ignition apparatus. The first point considered will be the common methods of generating the electricity, then the appliances to utilize it and produce the required spark in the cylinder.

Current Production by Chemical Action.—The simplest method of current generation is by various forms of chemical current producers which may be either primary or secondary in character. A simple form of cell is shown in section at Fig. 171, A, and as the action of all devices of this character is based on the same principles it will be

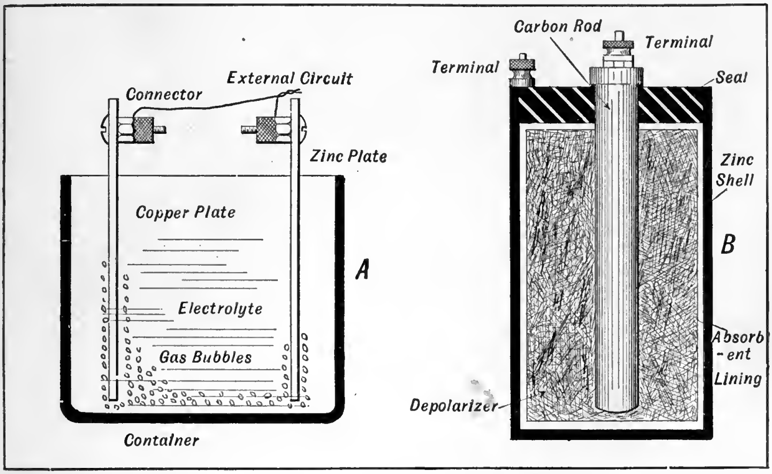


Fig. 171.—Simple Primary Cells Used to Produce Electric Current. A—Form to Show Principle of Current Production by Chemical Action. B—Dry Cell, the Type Suitable for Automobile Service.

well to consider the method of producing electricity by the chemical action of a fluid upon a metal. The simple cell shown consists of a container which is filled with an electrolyte which may be either an alkali or acid solution. Immersed in the liquid are two plates of metal, one being of copper, the other zinc. A wire is attached to each plate by means of suitable screw terminals.

If the ends of the plates which are not immersed in the solution are joined together a chemical action will take place between the electrolyte and the zinc plate; in fact, any form of cell consists of dissimilar elements which are capable of conducting electricity immersed in a liquid which will act on one of them more than the other. The chemical action of electrolyte on the zinc liberates gas bubbles which are charged with electricity and which deposit themselves on the copper plate. The copper element serves merely as a collecting member and is termed the "positive" plate, while the zinc which is acted upon by the solution is termed the "negative" member. The flow of current is from the zinc to the copper plate through the electrolyte and it is returned from the copper plate to the zinc element by the wiring which comprises the external circuit.

While in the cell shown zinc and copper are used, any other combination of metals between which there exists a difference in electrical condition when one of them is acted upon by a salt or acid may be employed. Any salt or acid solution will act as an electrolyte if it will combine chemically with one of the elements and if it does not at the same time offer too great a resistance to the passage of the electric current. The current strength will vary with the nature of the elements used, and will have a higher value when the chemical action is more pronounced between the negative member and the electrolyte.

As the vibrations which obtain when the automobile is driven over highways makes it difficult to use cells in which there is a surplus of liquid, a form of cell has been devised in which the liquid electrolyte is replaced by a solid substance which cannot splash out of the container even if the cell is not carefully sealed. A current producer of this nature is depicted in section at Fig. 171, B. This is known as a dry cell and consists of a zinc can in the center of which a carbon rod is placed. The electrolyte is held close to the zinc or negative member by an absorbent lining of blotting paper, and the carbon rod is surrounded by some depolarizing material. The top of the cell is sealed with pitch to prevent loss of depolarizer.

The depolarizer is needed that the cell may continue to generate current. When the circuit of a simple cell is completed the current generation is brisker than after the cell has been producing electricity for a time. While the cell has been in action the positive element becomes covered with bubbles of hydrogen gas, which is a poor conductor of electricity and tends to decrease the current output of the cell. To prevent these bubbles from interfering with current generation some means must be provided for disposing of the gas. In dry cells the hydrogen gas that causes polarization is combined with oxygen gas evolved by the depolarizing medium and the combination of these two gases produces water which does not interfere with the action of the cell. Carbon is used in a dry cell instead of copper because it is a cheaper material and the electrolyte is a mixture of sal-ammoniac and chloride of zinc which is held in intimate contact with the zinc shell which forms the negative element by the blotting-paper lining.

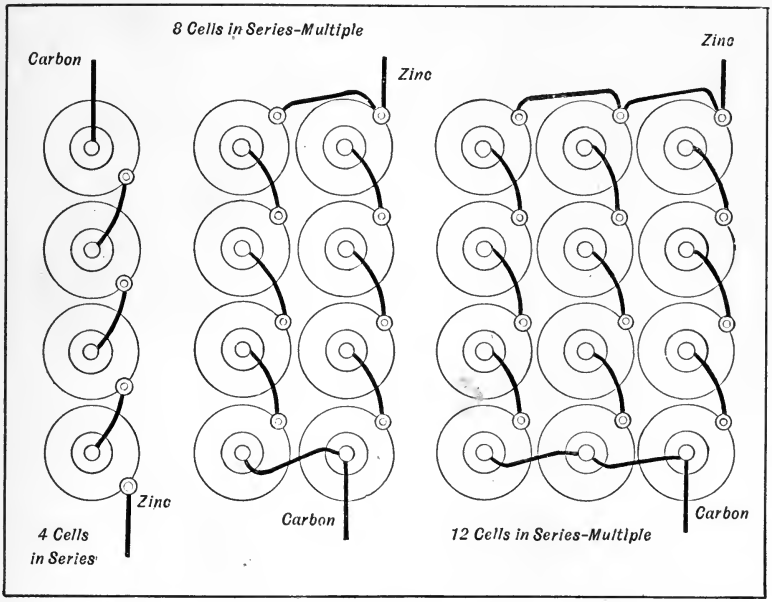


Fig. 172.—Methods of Joining Dry Cells to Form Batteries of Varying Value.

A single dry cell will not produce sufficient current to ignite the charge of gas in the engine cylinder, therefore it is common practice to combine two or more cells in such a manner that batteries are formed which will give more current than a single cell. If it is desired to increase the voltage the cells are connected in series, as shown at Fig. 172. If one dry cell will produce one and one half volts and six volts are needed to produce the spark in the engine cylinder, the current value of one dry cell is augmented by coupling three others to it in a series connection. When cells are connected in series it is the unlike elements which are joined together. For example, the zinc of one cell should be joined with the carbon of the adjacent member by a flexible conductor. This will leave the carbon of one end cell and the zinc of the other end cell free so that they can be joined to the apparatus in the outer circuit.

When it is desired to obtain more amperage or current quantity than could be obtained from a single cell they are joined in series-multiple connection. With this method of wiring two or more sets of four cells which have been joined in series are used. The zinc of one set is joined with the zinc element of the other and the two carbons are similarly connected. Any number of sets of cells may be connected in series multiple and the amperage of the combination is increased proportionately to the number of sets joined together in this manner.

When dry cells are connected in series the voltage of one cell is multiplied by the number of cells and the amperage obtained from the set is equal to that of one cell. When connected in series multiple, as shown at Fig. 172, the amperage is equal to two cells and the voltage produced is equivalent to that obtained from four cells. When twelve cells are joined in series multiple the amperage is equal to that of one cell multiplied by three while the voltage or current pressure is equal to that produced by one cell multiplied by the number of cells which are in series in any one set. By properly combining dry cells in this manner batteries of any desired current strength may be obtained.

The terms "volt" and "ampere" are merely units by which current strength is gauged. The volt is the unit of pressure or potential which exists between the terminals of a circuit. The ampere measures current quantity or flow and is independent of the pressure. One may have a current of high amperage at low potential or one having great pressure and but little amperage or current strength. Voltage is necessary to overcome resistance while the amperage available determines the heating value of the current. As the resistance to current flow increases the voltage must be augmented proportionately to overcome it. A current having the strength of one ampere with a pressure of one volt is said to have a value of one watt, which is the unit by which the capacity of generators and the amount of current consumption is gauged.

One of the disadvantages of primary cells, as those types which utilize zinc as a negative element are called, is that the chemical action produces deterioration and waste of material by oxidization. Dry cells are usually proportioned so that the electrolyte and depolarizing materials become weaker as the zinc is used and when a dry cell is exhausted it is not profitable to attempt to recharge it because new ones can be obtained at a lower cost than the expense of renewing the worn elements would be.

The number of dry cells necessary will vary with the system of ignition employed and the size of the motor. While two or three cells will ignite small engines such as used in motorcycles, five or six will be needed on automobile engines employing high-tension ignition. When the make-and-break system, or low-tension method, is used eight or ten cells are necessary. If the engine is a multiple cylinder one, it will draw more current than a single cylinder type because of the greater frequency of sparks. On four-cylinder cars dry cells should be joined in multiple series, which is the most economical arrangement. Cells used in multiple connection are more enduring than if the same number were used independently in single-series connection. A disadvantage of a dry cell battery is that it is suited only for intermittent service and it will soon become exhausted if used where the current demands are severe. For this reason most automobiles in which batteries are used for ignition employ storage or secondary batteries to furnish the current regularly used and a set of dry cells is provided for use only in cases of emergency when the storage battery becomes exhausted.

Principles of Storage Battery Construction.—Some voltaic couples are reversible, i. e., they may be recharged when they have become exhausted by passing a current of electricity through them in a direction opposite to that in which the current flows on discharge. Such batteries are known as "accumulators" or "storage batteries." A storage battery belies its name as it does not store current and its action is somewhat similar to that of the simpler chemical cell previously described. In its simplest form a storage cell would consist of two elements and an electrolyte, as outlined at Fig. 173, A. The storage battery differs from the primary cell in that the elements are composed of the same metal before charging takes place, usually lead instead of being zinc or carbon. One of the plates is termed the "positive" and may be distinguished from the other because it is brown, or chocolate in color after charging, while the negative plate is usually a light gray or leaden color. The active material of a charged storage battery is not metallic lead but oxides of that material.

The simple form shown at A consists of two plates of lead which are rolled together separated by insulating bands of rubber at the top

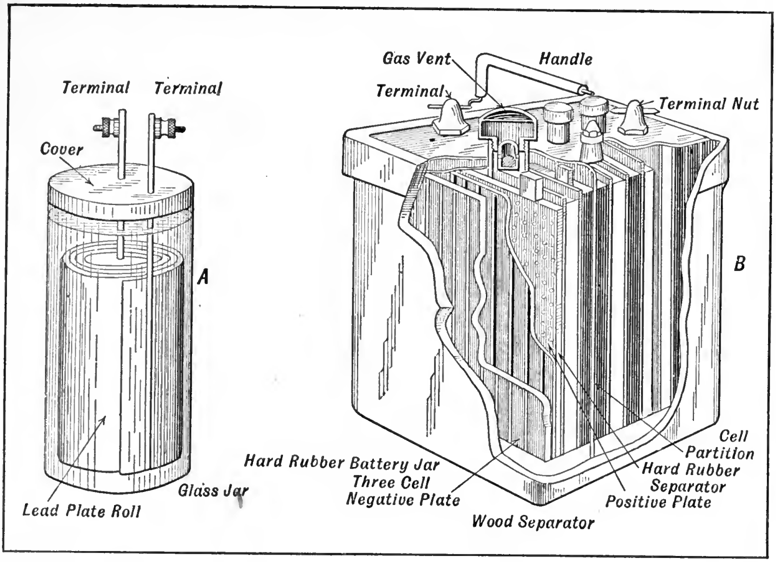


Fig. 173.—Types of Accumulators or Storage Batteries. A—Simple Form of Cell. B—Battery Composed of Three Cells, Such as Commonly Used for Motor Car Engine Ignition.

and bottom to keep them from touching. This roll is immersed in an electrolyte composed of a weak solution of sulphuric acid in water. Before such a cell can be used it must be charged, which consists of passing a current of electricity through it until the lead plates have changed their nature. After the charging process is complete the lead plates have become so changed in nature that they may be considered as different substances and a chemical action results between the negative plate and the electrolyte and produces current just as in the simple cell shown at Fig. 171, A. When the cell is exhausted the plates return to their metallic condition and are practically the same, and as there is but little difference in electrical condition existing between them, they do not deliver any current until electricity has been passed through the cell so as to change the lead plates to oxides of lead instead of metallic lead.

When storage cells are to be used in automobile work they are combined in a single containing member, as shown at Fig. 171, B, which is a part sectional view of a Geiszler storage battery. The main containing member, a jar of hard rubber, is divided into three parts. Each of these compartments serves to hold the elements comprising one cell. The positive and negative plates are spaced apart by wood and hard rubber separators which prevent short circuiting between the plates. After the elements have been put in place in the compartments forming the individual cells of the battery, the top of the jar is sealed by pouring a compound of pitch and rosin, or asphaltum, over plates of hard rubber, which keeps the sealing material from running into the cells and on the plates. Vents are provided over each cell through which gases produced by charging or discharging are allowed to escape. These are so formed that while free passage of gas is provided for, it is not possible for the electrolyte to splash out when the vehicle is in motion.

It will be evident that this method of sealing would not be practical on a cell where the members attacked by the acid had to be replaced from time to time, but in a storage battery only the electrolyte need be renewed. When the plates are discharged they are regenerated by passing a current of electricity through them. New electrolyte can be easily inserted through caps in which the vents are screwed. The cells of which a storage battery is composed are joined together at the factory with bars of lead which are burned in place and only two free terminals are provided by which the battery is coupled to the outer circuit.

The capacity of a storage battery depends upon the size and the number of plates per cell, while the potential or voltage is determined by the number of cells joined in series to form the battery. Each cell has a difference of potential of two and two tenths volts when fully charged, therefore a two-cell battery will deliver a current of four and four tenths volts and a three-cell type, as shown at Fig. 173, B, will give about six and six tenths volts between the terminals. In the form shown each cell is composed of four plates and their separators. Two of the plates are positive, the remaining two negative members. The size of storage battery to be used depends upon the number of cylinders of the engine. Four-cylinder motors usually take a six-volt, sixty-ampere-hour battery, but it is desirable to supply a six-volt battery having eighty-ampere-hour capacity for six-cylinder motors.

When chemical current producers are depended upon to supply the electricity used for ignition, two distinct sets are provided, one for regular service and the other for emergency use in event of failure of that which is depended upon regularly. The common practice is to provide an accumulator or storage battery for normal use and a set of dry cells, which are cheaper in first cost and which do not deteriorate if not used for some time, for emergency service. When two sources of current are thus provided, a switch is included in the circuit so that either set may be used at will. The zinc terminal of the dry battery and the negative terminal of the storage battery are joined together by a suitable conductor and are grounded by running the wire attached to them to some metal part of the chassis such as the crank case or frame side member. The remaining terminals, which are the positive of the storage battery and the carbon of the dry cell, are coupled to distinct terminals on the switch block.

The fact that any battery cannot maintain a constant supply of electricity has militated against their use to a certain extent and the modern motorist demands some form of mechanical generator driven from the power plant, which will deliver an unfailing supply of electricity. The strength of batteries is reduced according to the amount of service they give. The more they are used the weaker they become. The modern multiple cylinder engines are especially severe in their requirements upon the current producer and the rapid sequence of explosions in the average four- or six-cylinder motor produce practically a steady drain upon the battery. When dry cells are used their discharge rate is very low and as they are designed only for intermittent work, when the conditions are such that a constant flow of current is required, they are unsuitable and will soon deteriorate.

The same objection applies to a certain extent to the storage battery, though this form of current producer is more practical for use where a steady flow of current is desired. The same objection advanced against the dry cell that the current becomes weaker as the cell is used applies equally well to the storage battery. This has made it imperative that one of the various forms of mechanical generators be employed as a source of electricity for regular ignition service. Such devices are driven directly from the engine and the amount of energy they deliver is proportionate to the speed of rotation. When the engine is accelerated and more electricity is needed, the mechanical generator speed increases directly as that of the driving source, and more current is delivered as the demands upon the generator augment.

Dynamo Electric Machines.—Two distinct types of mechanical generators are in common use and while their principles of action are practically the same, they differ somewhat in construction and application. The forms first used to succeed the battery were modifications of the larger dynamo electric machines used for delivering current for power and lighting. Later developments resulted in the simplification of the dynamo, by which it was made lighter and more efficient, and the modern magneto igniter is the form usually furnished on conventional power plants. A dynamo uses electro-magnets to produce a magnetic field for the armature to revolve in and is necessarily somewhat heavier and larger than a magneto of equal capacity because the field in the latter instrument is produced by permanent magnets. An important advantage in using the magneto form of construction is that the weight of the windings is saved because the permanent magnets retain their magnetism and do not require the continual energizing that an electro-magnet demands.

The dynamo construction is superior where a continual drain is made upon the apparatus, because if a magneto is used continuously the magnets are liable to lose some of their strength and as the magnetic field existing between the pole pieces decreases in value the amount of current delivered by the apparatus diminishes in direct proportion. When electro-magnets are used the constant flow of electrical energy through the windings keeps them energized to the proper point, and as current is continuously supplied, the strength of the magneto field remains constant. The dynamo form of generator is utilized where currents of considerable value are needed such as in electric lighting systems now so widely used on automobiles.

Where the device is depended upon only to furnish ignition current the magneto is preferred by most engineers because it is simpler and lighter than the dynamo, and also because it may be made in such form that it will comprise a complete ignition system in itself. When a dynamo is utilized the conditions are just the same, as far as necessary auxiliary apparatus is concerned, as though batteries were used and one merely substitutes a mechanical generator in place of the chemical cells. The same auxiliary apparatus necessary in one case is employed in the other as well.

A dynamo or magneto produces electricity by an inductive action, which is a reversal of the phenomena by which a current of electricity flowing around a bar of iron or steel makes a magnet of it. If a wire through which a current of electricity is flowing will magnetize a bar of iron, a bar of steel which is already magnetized will generate a current of electricity by induction in a conductor surrounding it if either the magnet or the coil of wire is moved in such a manner that the magnetic influence is traversed or traverses the wire. In a dynamo or magneto a coil of wire mounted on a suitable armature is revolved between the pole pieces of the field magnet and as the conductor cuts across the zone of magnetic influence a current of electricity is induced in the coil. The faster the coil is rotated the more rapidly the winding passes through the magnetic field. As an electrical impulse is produced every time the magnetic field is traversed, it is patent that the greater number of electrical impulses will produce a current of higher value.

A sectional view of a typical dynamo electric machine of conventional design is shown at Fig. 174. All parts are clearly indicated and there should be no difficulty in understanding the principles of operation. The three main portions of the dynamo are the field magnets, which produce the magnetic field, the armature, which carries the coils of wire and which is mounted between the extremities or pole pieces of the magnet, and the brushes, which bear against segments of a collecting device known as a commutator serving to convey the current to terminals which are joined to the outer circuit. In the form shown the field magnets are composed of a number of iron stampings which are surrounded by a coil of wire, and two such magnets are provided, one above, the other below the armature. The armature is supported on a shaft mounted in ball bearings so that it will turn with minimum friction. The whole mechanism is protected by an outer casing.

The device shown is a constant speed dynamo, i. e., it should be operated at a certain speed to obtain the best results. If run faster

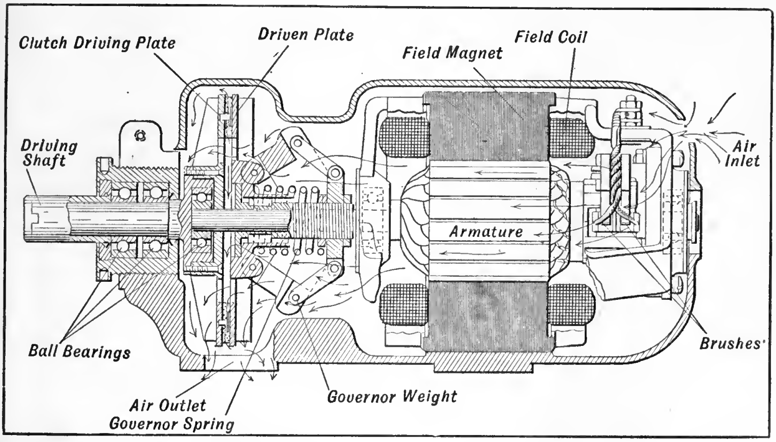


Fig. 174.—Gray & Davis Governed Dynamo, an Appliance for Producing Electricity by Mechanical Means.

than the speed for which it is designed the excess current generated is liable to burn out the windings of the field magnet. For this reason a governor of the fly ball type is interposed between the dynamo armature and the driving shaft coupled to the source of power. At all normal speeds the tension of the governor spring keeps the two plates of the clutch in contact and the armature is turned at the same speed as the driving shaft.

Should the driving shaft speed exceed a certain predetermined limit the governor weights will fly out by centrifugal force and the governor spring will be compressed so the driving and driven plates of the clutch are separated and the driving shaft revolves independently of the armature. As soon as the armature speed becomes reduced sufficiently to allow the governor spring to overcome the centrifugal force and draw back the governor weights, the clutch plates are again brought into contact and the armature is again joined to the driving shaft.

A current of air is kept circulating through the casing by means of the fan action of the reënforcing webs of the clutch plate, the ob-

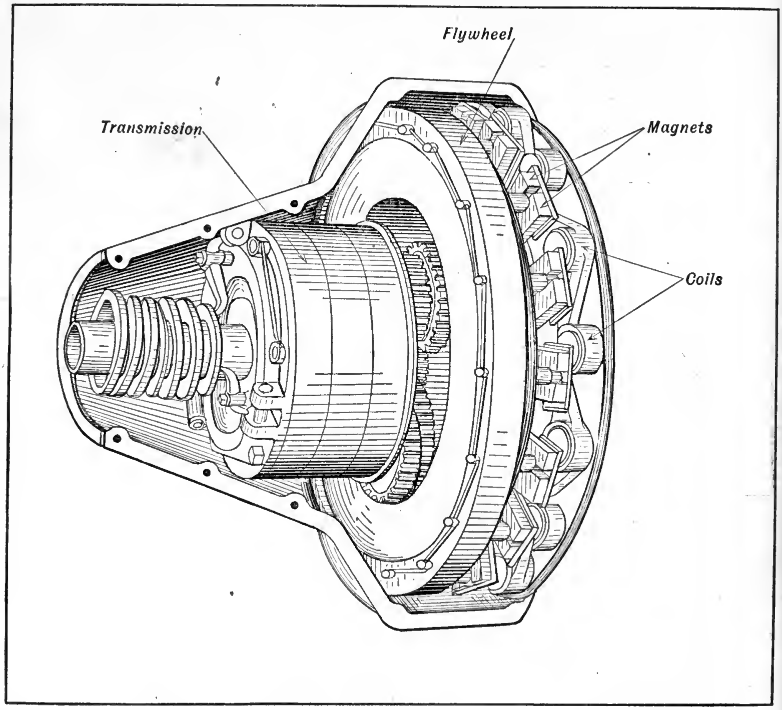


Fig. 175.—Distinctive Form of Current Producer Used on Ford Cars is Incorporated in the Power Plant Fly Wheel.

ject being to absorb any heat which may be produced while the dynamo is in action. An appliance of this nature may be driven from the engine by belt, chain, or gear connection. It will deliver low voltage current which must be transformed by means of an induction coil to current of higher value in order that it may be successfully utilized to produce the spark in the combustion chambers of the engine.

A very ingenious application of the dynamo is shown at Fig. 175. The electric generator is built in such a manner that it forms an integral part of the power plant. The magneto field is produced by a series of revolving magnets which are joined to and turn with the fly wheel of the motor. The armature coils are carried by a fixed plate which is attached to the engine base. This apparatus is really a magneto having a revolving field and a fixed armature, and as the magnets are driven from the fly wheel there is no driving connection to get out of order and cause trouble. As the coils in which the current is generated are stationary, no commutator or brushes are needed to collect the current because the electricity may be easily taken from the fixed coils by direct connection. It has been advanced that this form of magneto is not as efficient as the conventional patterns because more metal and wire are needed to produce the current required. As the magnets which form the heavier portion of the apparatus are joined to the fly wheel, which can be correspondingly lighter, this disadvantage is not one that can be considered seriously because the magnet weight is added to that of the motor fly wheel, the combined weight of the two being that of an ordinary balance member used on any other engine of equal power.

Timer and Distributor Forms.—Anyone familiar with the basic principles of internal combustion engine action will recognize the need of incorporating some device in the ignition system, which will insure that the igniting spark will occur only in the cylinder that is ready to be fired and at the right time in the cycle of operations. There is a certain definite point at which the spark must take place, this having been determined to be at the end of the compression upstroke, at which time the gas has been properly compacted and the piston is about to start returning to the bottom of the cylinder again. Timers or distributors are a form of switch designed so that hundreds of positive contacts which are necessary to close and open the circuit may be made per minute without failure.

When the device is employed to open and close a low-tension circuit, it is known as a commutator or timer, and when used in connection with current of high voltage they are called secondary distributors. Certain constructional details make one form different from the other, and while they perform the same functions they vary in design. Such distributing devices are always driven by positive gearing from the engine and are timed so the sparks will occur in the cylinders at just the proper ignition time. The usual construction is to use a fixed case which carries one or more contact members suitably disposed around its periphery and a central revolving member or cam which contacts with the points on the body of the device to close any desired circuit. On a four-cycle engine the cam is revolved at one half the engine speed and the timer is usually driven from the cam shaft. In two-cycle engines the revolving member of the timer turns at engine speed, and should be driven directly from and at the same speed as the crank shaft.

Simple timer forms suitable for one-cylinder motors are shown at Fig. 175. The simplest one, depicted at A, consists of a rocking member of fiber or other insulating material which carries a steel spring that is normally out of engagement with the surface of the cam. When the point of the cam brushes by the contact spring, any circuit in which the device is incorporated will be closed and current will flow from the battery or dynamo to the transformer coils and spark plugs which are depended on to furnish a spark of sufficient intensity to insure ignition of the gas. It is desirable that the member which carries the contact spring be capable of a certain degree of movement, in order that the spark time may be advanced or retarded to suit various running conditions. In the form shown if the top of the casing is pushed in the direction of the arrow, the contact spring will come in contact with the point of the cam which is turning in the direction indicated sooner than it will if the base member is rocked in a reverse direction and the contact spring pulled away from the point of the cam instead of being moved forward to meet it. The wipe contact form is the simplest, but the spring is liable to wear at the point of contact and may break off and cause trouble. Such a device is more suitable for low-speed engines than it is for those which have high crank-shaft velocity.

The single-cylinder timer depicted at B is a form that is widely used on high-speed engines and contact is made between a pair of platinum contact points which just touch each other instead of wiping. Platinum is a material that is not affected by the arcing or heat of the spark as much as steel or brass would be and provides a more positive contact. In the wipe contact form the continual brushing action of the cam against the spring tends to keep the contact surfaces clean, but this condition does not obtain in the simple touch contact of the form shown at B. The casing is rocked in the direction of

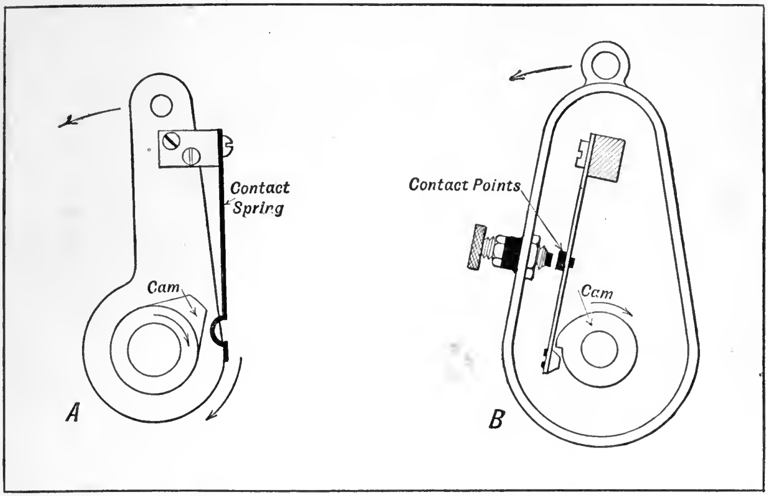


Fig. 176.—Simple Forms of Contact Breakers Used on One-Cylinder Engines. A—Wipe Contact. B—Touch Contact.

the arrow to advance a spark in either case. The form shown at B is more economical of current because the contact is shorter and is more suitable for high-speed engines. While the forms considered prove practical in their application to simple one- and two-cylinder engine forms, they are very heavy or clumsy appliances when used for four-cylinder engines, as it is very hard to assemble the spring element so that the contact will take place at the proper point in all cylinders.

When a timer is to be used in connection with a four- or six-cylinder engine the compact form shown at Fig. 177, A, is usually adopted. This has many desirable features and permits of timing the spark with great accuracy. The contact segments are spaced on quarters and are imbedded in a ring of fiber which is retained in a casing of aluminum. The central revolving element carries a lever which has a roll at one end and a tension spring designed to keep the roller in contact with the inner periphery of the fiber ring at the other. The segments are of steel and are accurately machined and hardened,

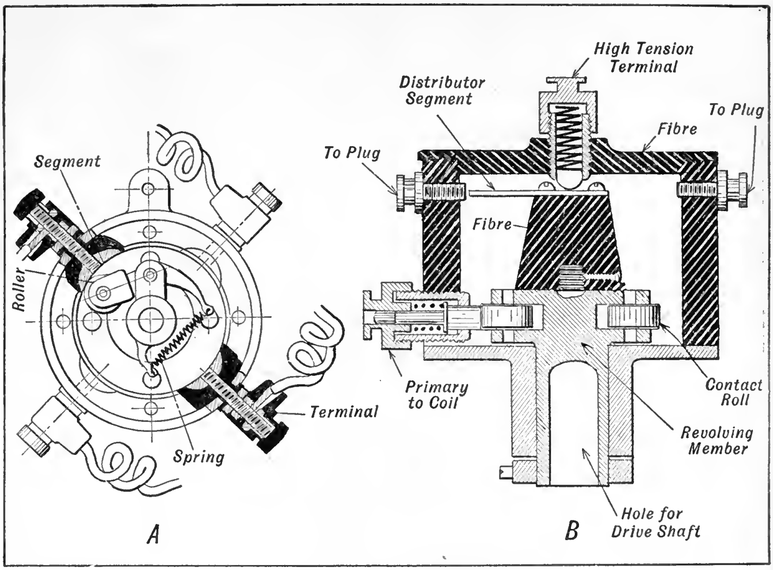


Fig. 177.—Timers Employed on Four-Cylinder Engines. A—Four-Contact Device for Commutating Primary Current. B—Combined Timer and Distributor Directs Both High- and Low-Tension Energy.

and as the surface of the roller is also hardened, this form of timer is widely used because it provides a positive contact and works smoothly at all engine speeds.

A secondary distributor which is employed to distribute both high- and low-tension current is shown at Fig. 177, B. This consists of a primary timing arrangement in the lower portion, and a secondary current-distributing segment at the upper portion. The central revolving member carries as many rolls as there are cylinders to be fired, these being spaced at the proper points in the circle to insure correct timing. One primary contact member is screwed into the casing, this contacting with the rolls as they revolve. At the upper portion of the case a number of terminals are inserted from which wires lead to plugs in the cylinders. When a timer of the form shown at Fig. 177, A, is used, a separate induction coil is needed for each cylinder and the number of units in the coil box and contact points on the timer will be the same as the number of cylinders to be fired. When a secondary distributor is employed but one induction coil is needed for all cylinders, because the secondary or high-tension current from one unit is distributed to the spark plugs at the proper time. Various wiring diagrams will be presented to show the methods of using timers and distributors. It will be noticed that the high-tension portion of the distributor is well insulated from the primary circuit closing member at the lower end. This is necessary because current of high voltage is much more difficult to handle than that of lower pressure, and it is more liable to short circuit.

The arrangement of the contact points for various numbers of cylinders in roller contact timers is shown at Fig. 178. At A but

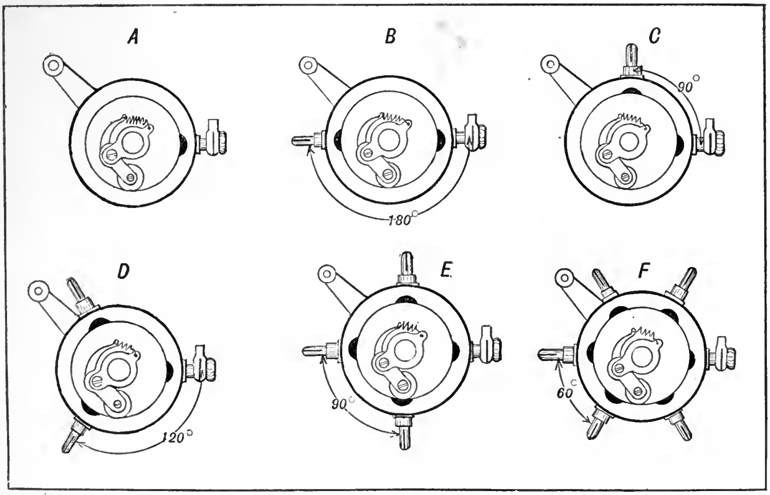


Fig. 178.—Showing Disposition of Contact Points on Timers for Number of Cylinders. A—One-Cylinder Type. B—Arrangement for Two-Cylinder Opposed Motor. C—Contacts Separated by 90 Degrees in One Direction and 270 Degrees in the Other when Used on Two-Cylinder Vertical Engine with Opposed Crank Pins. D—Three-Cylinder Form. E—Suitable for Four-Cylinder Engines. F—Type Employed on Six-Cylinder Power Plants.

one segment is provided, this obviously serving only one cylinder. The form depicted at B is utilized with a double-cylinder opposed motor or a twin-cylinder vertical type in which both connecting rods act on a common crank pin or crank pins in the same plane. As the explosions are evenly spaced and the intervals separating the sparks are equal, the contact segments are placed diametrically opposite and are separated by a space of 180 degrees. If the two-cylinder engine is a vertical form having opposed cranks, the explosions will not be separated by equal intervals, so the segments must be placed to compensate for the difference which exists in the time interval separating the power impulses. Two contact segments are imbedded in the insulating ring, the contacts being separated by a space of 90 degrees on one side and 270 degrees on the other. This form of timer is seldom used at the present time because the two-cylinder engine of the pattern for which it is adapted has been practically discarded.

When three cylinders are used the contact points are separated by a space of 120 degrees, as shown at D. In a four-cylinder timer the contact segments are spaced on quarters of the circle and are separated by a space equal to 90 degrees. With a six-cylinder motor six segments are necessary, these being separated by a space of 60 degrees, as shown at F. Before considering the other components of a battery ignition system it would be well to outline the essential elements of a simple ignition group so that the circuit and flow of current may be easily followed.

Essential Elements of Simple Ignition System.—The current obtained from the dry or storage battery or low-tension dynamo or magneto is not sufficiently powerful to leap the gap which exists between the points of the spark plug in the cylinder unless it is transformed to a current having a higher potential. The air gap between the points of the spark plug has a resistance which requires several thousand volts pressure to overcome, and as a battery will only deliver six to eight volts, it will be evident that, unless the current value is increased, it could not produce a spark between the plug electrodes.

The low voltage current is transformed to one of higher potential by means of a device known as the induction coil. The current from the battery is passed through the primary coil, which is composed of several layers of coarse wire wound around a core of soft iron wire to form an electro-magnet as shown at Fig. 179. Surrounding this primary coil is one composed of a large number of turns of finer

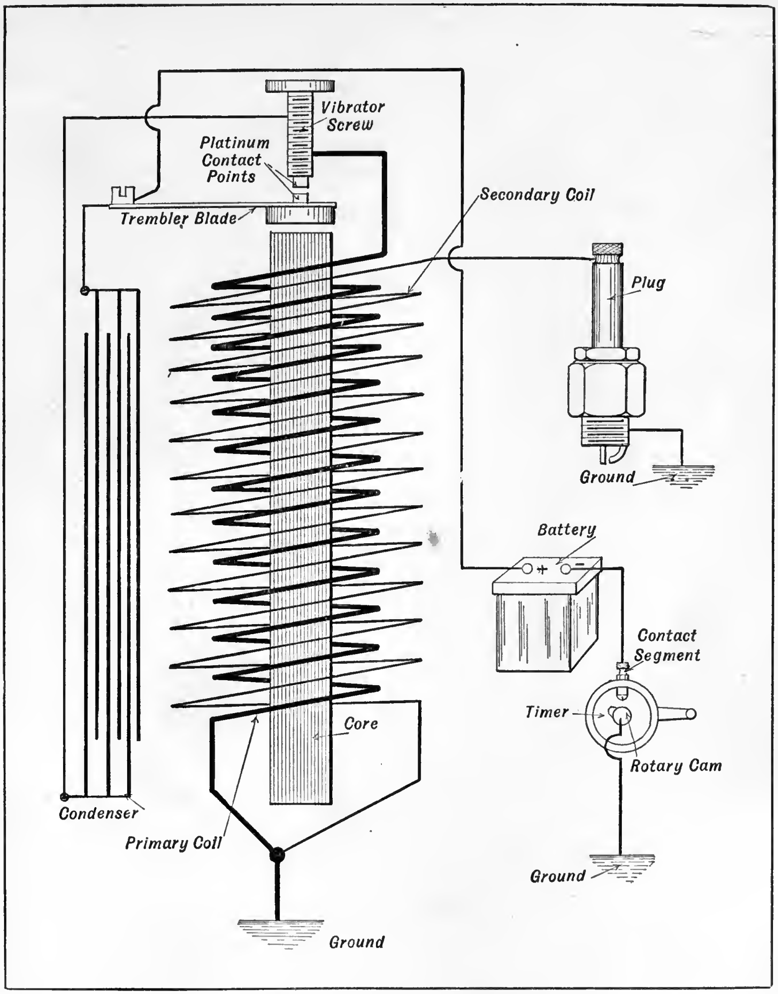


Fig. 179.—Simple Ignition System for One-Cylinder Motor Showing Important Components and Their Relation to Each Other.

conductor. When a current of electricity of low voltage passes through the primary coil, a current of very high electro-motive force is produced in the secondary winding. One end of each coil is grounded. The free end of the primary coil is coupled to the battery while that of the secondary coil is attached to the insulated terminal of the spark plug.

The arrangement of wiring at Fig. 179 is that employed in a typical transformer coil which is used to increase the voltage of the current sufficiently to cause it to overcome the resistance of the air gap at the spark plug and produce a spark which will ignite the gas. In the primary circuit are included a suitable timer for closing the circuit, a battery of chemical cells to supply the energizing current, and a vibrator or make-and-break mechanism on the coil. The secondary circuit includes the spark plug and the secondary winding of the coil.

When the primary circuit is closed by the cam of the timer making contact with the segment, the current from the battery flows through the primary coil of the transformer. This magnetizes the core which draws down the trembler blade, this in turn separating the platinum contact point of the vibrator and interrupting the current. As soon as the current is interrupted at the vibrator the core ceases to be a magnet and the trembler blade flies back and once again closes the circuit between the platinum points. Every time the circuit is made and broken at the vibrator an electrical impulse is induced in the secondary winding of the coil.

The vibrator may be adjusted so that it will make and break the circuit many times a minute and as a current of high potential is produced in the secondary winding with each impulse, a small spark will be produced between the points of the spark plug. The condenser is a device composed of layers of tin foil separated from each other by waxed or varnished paper insulation. It is utilized to absorb some of the excess current produced between the vibrator points, which causes sparking. This extra current is induced by the action of the primary coils of wire upon each other and by a reversed induction influence from the secondary coil.

If this current is not taken care of, it will impede the passage of the primary current and the sparks are apt to burn or pit the platinum contact points of the vibrator. When a condenser is provided the extra primary current is absorbed by the sheets of tin foil which become charged with electricity. When contact is made again the condenser discharges the current in the same direction as that flowing through the primary coil from the battery and the value of the latter is increased proportionately. There is less sparking between the vibrator points and a stronger current is induced in the secondary coil which in turn produces a more intense spark between the points of the spark plug.

A typical induction coil such as would be used for firing a one-cylinder engine if used with a simple timer, or a multiple-cylinder

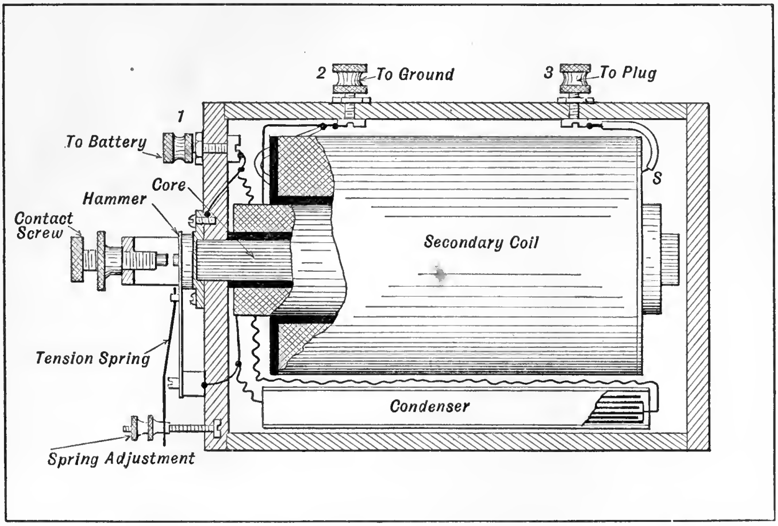


Fig. 180.—Part Sectional View of Simple Induction Coil, an Important Component of All Battery Ignition Groups and Sometimes Used with Magnetos.

engine if used in connection with a combined timer and distributor, is depicted in part section at Fig. 180. It will be observed that three terminal screws are provided on the box, one designed to be attached to the battery, the other two to the spark plug and ground, respectively. The terminal to which the battery wire is attached is coupled to the bridge member which carries the contact screw while the vibrator blade is connected with one of the ends of the primary coil. The other end of the primary coil goes to the terminal which is joined to the ground. The condenser is shunted in between the vibrator points, i. e., one of the leads is attached to terminal No. 1 while the other is soldered to the end of the primary coil which goes on the vibrator spring member. One end of the secondary coil is attached to terminal No. 2, which is grounded on some metal part of the chassis frame, while the other end is secured to terminal No. 3, which is joined to the spark plug electrode. After the various components of the induction coil are assembled in the box and the connections made as indicated, the spaces between the sides of the box and the coil member are filled with an insulating compound composed of beeswax, pitch and rosin. This holds everything rigidly in place and prevents the wire joints loosening through vibration.

The method of connecting the members of an induction coil, shown at Fig. 180, is a conventional one, though the connections will differ with the nature of the circuit of which the coil forms a part and the number of units comprising the coil assembly. When such devices are employed for igniting multiple-cylinder motors, the internal wiring is very much the same as though the same number of box coils for single-cylinder ignition were combined together by outside conductors. The number of terminals provided will vary with the number of units.

Various forms of induction coils are depicted at Fig. 181. That at A is a simple unit form in which the coil is attached directly to the spark plug, which in turn is screwed into the cylinder. On this coil but two primary terminals are attached, one being connected to the insulated contact point on the timer, the other being grounded, or attached to the battery. Coils of this type have been very popular in marine application because of the simple and direct wiring possible, but they have not been used in connection with automobile engine ignition to any extent. The form shown at B is a simple dash coil for one-cylinder use which has three terminals, one being used for a secondary lead to the spark plug, the other two being joined to the battery and ground respectively, as shown at Fig. 180.

The form of coil shown at C is a two-unit member designed for double-cylinder ignition. As the switch is mounted on the coil box to use two sets of batteries, six terminals are provided on the bottom of the coil case. Two of these are attached directly to the insulated

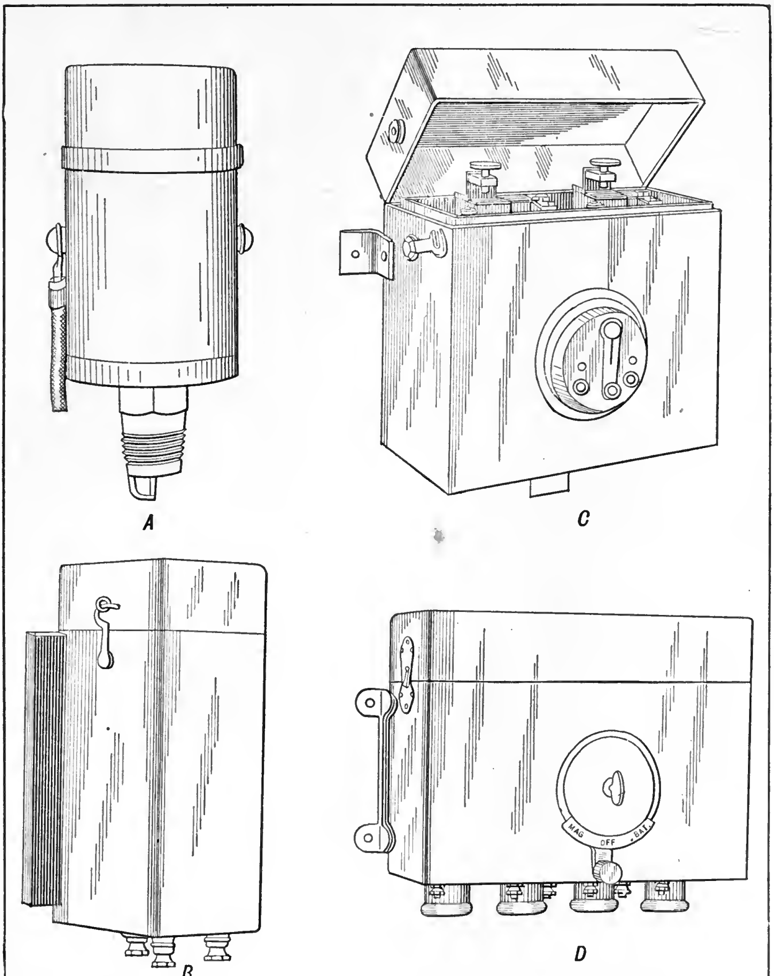


Fig. 181.—Conventional Induction Coil Forms. A—Coil Unit and Plug Combined. B—Simple Box Coil for One-Cylinder Ignition. C—Two-Unit Coil for Two-Cylinder Motors. D—Four-Unit Coil for Four-Cylinder Service.

contact point of the timer; two others which are enclosed in hard rubber insulating caps are attached to the spark plugs. The two immediately under the switch are attached to the free terminals of the battery, two sets being provided, one being coupled to each side of the switch.

With a four-unit coil, as shown at D, ten terminals are provided because of the attached switch. Four go to the spark plugs, four to the insulated segments of the timer and two to the battery, or battery and magneto or dynamo, as the case may be. In modern coils the units may be removed from the box without disturbing any internal connection, and a new one slipped in its place if it does not function properly. Special care is taken in insulating the high-tension terminal by means of rubber caps which surround the wire, and care is taken to have the vibrator contact points readily accessible for inspection, cleaning, or adjustment.

Spark Plug Design and Application.—With the high-tension system of ignition the spark is produced by a current of high voltage jumping between two points which break the complete circuit, which would exist otherwise in the secondary coil and its external connections. The spark plug is a simple device which consists of two terminal electrodes carried in a suitable shell member, which is screwed into the cylinder. Typical spark plugs are shown in section at Fig. 182 and the construction can be easily understood. The secondary wire from the coil is attached to a terminal at the top of a central electrode member, which is supported in a bushing of some form of insulating material. The type shown at A employs a molded porcelain as an insulator, while that depicted at B uses a bushing of mica. The insulating bushing and electrode are housed in a steel body, which is provided with a screw thread at the bottom, by which it is screwed into the combustion chamber.

When porcelain is used as an insulating material it is kept from direct contact with the metal portion by some form of yielding packing, usually asbestos. This is necessary because the steel and porcelain have different coefficients of expansion and some flexibility must be provided at the joints to permit the materials to expand differently when heated. The steel body of the plug which is screwed into the cylinder is in metallic contact with it and carries sparking points which form one of the terminals of the air gap over which the spark occurs. The current entering at the top of the plug cannot reach the ground, which is represented by the metal portion of the engine, until it has traversed the full length of the central electrode and overcome the resistance of the gap between it and the terminal point on the shell. The porcelain bushing is firmly seated against the

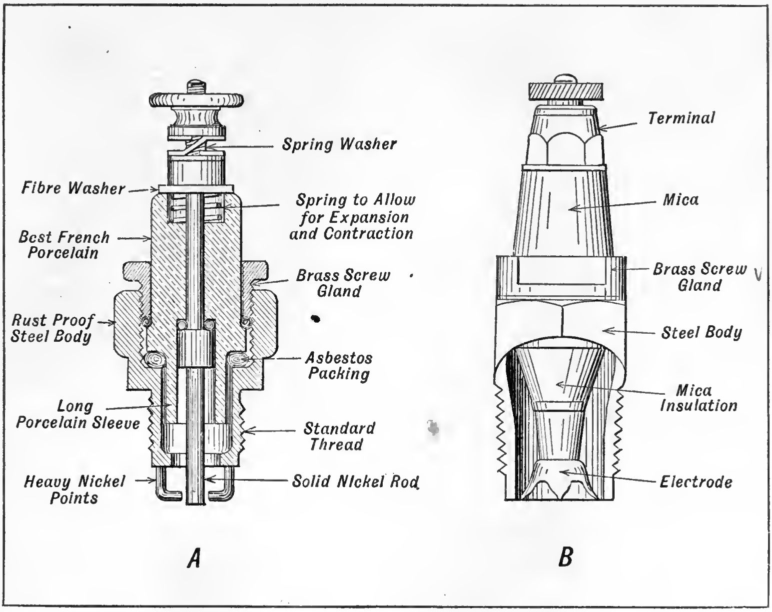


Fig. 182.—Spark Plug Construction Outlined. A—Sectional View of Porcelain Plug. B—Part Sectional View of Mica Plug.

asbestos packing by means of a brass screw gland which sets against a flange formed on the porcelain, and which screws into a thread at the upper portion of the plug body.

The mica plug shown at B is somewhat simpler in construction than that shown at A. The mica core which keeps the central electrode separated from the steel body is composed of several layers of pure sheet mica wound around the steel rod longitudinally, and hundreds of stamped steel washers which are forced over this member and compacted under high pressure with some form of a binding material between them. Porcelain insulators are usually molded from high grade clay and are approximately of the shapes desired by the designers of the plug. The central electrode may be held in

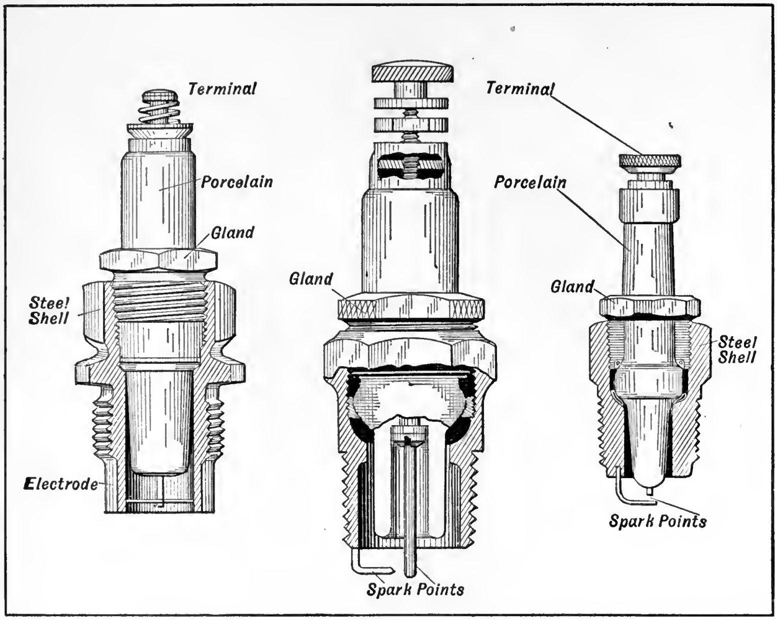


Fig. 183.—Three Forms of Spark Plugs in which Electrodes are Separated by Porcelain Insulation.

place by mechanical means such as nuts, packings, and a shoulder on the rod, as shown at A. Another method sometimes used is to cement the electrode in place by means of some form of fire-clay cement. Whatever method of fastening is used, it is imperative that the joints be absolutely tight so that no gas can escape at the time of explosion. With a mica plug the electrode and the insulating bushing are really a unit construction and are assembled in permanent assembly at the time the plug is made.

Other insulating materials sometimes used are glass, steatite (which is a form of soapstone), and lava. Mica and porcelain are the two common materials used because they give the best results. Glass is liable to crack while lava or the soapstone insulating bushings absorb oil. The spark gap of the average plug is equal to about $\frac{1}{32}$ of an inch for coil ignition and from $\frac{1}{40}$ to $\frac{1}{64}$ of an inch when used in magneto circuits. A simple gauge for determining the gap setting is the thickness of an ordinary visiting card for magneto plugs, or a space equal to the thickness of a worn dime for a coil plug. The insulating bushings are made in a number of different ways, and while details of construction vary, spark plugs do not differ essentially in design. Three different forms of plugs using porcelain insulation are shown in part section at Fig. 183. Porcelain is the material most widely used because it can be glazed so that it will not absorb oil, and it is subjected to such high temperature in baking that it is not liable to crack when heated.

The spark plugs may be screwed into any convenient part of the combustion chamber, the general practice being to install them in the

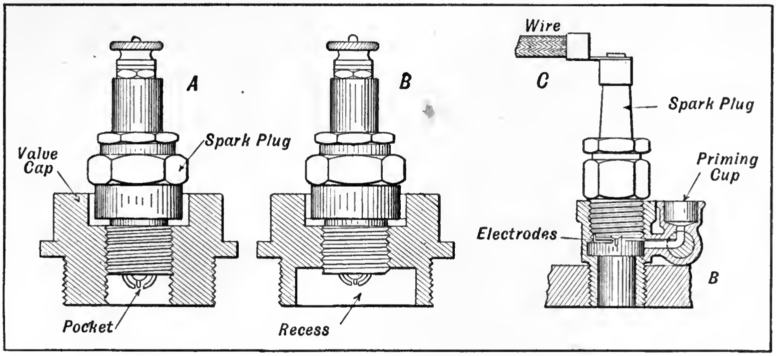


Fig. 184.—Methods of Installing Spark Plugs of Conventional Form. A—Incorrect Method. B—Correct Installation in Valve Chamber Cap. C—Combined with Cylinder Priming Device or Compression Relief Cock.

caps over the inlet valves, or in the side of the combustion chamber, so the points will be directly in the path of the entering fresh gases from the carburetor. The methods of spark plug installation commonly used are shown at Fig. 184. At A the plug is screwed into a threaded hole which passes through the valve cap in such a manner that the points are in a pocket. This is not considered to be as good as the method depicted at B, where the interior of the valve cap is recessed out so there is considerable space around the spark point. When the electrodes are carried in a pocket they are more liable to become short circuited by oil or carbon accumulations, because it is difficult for the fresh gases to reach them and the pocket tends to retain heat. Ignition is not so certain because some of the burned gases may be retained in the pocket and prevent the fresh gas from getting in around the spark gap. With a recess, as shown at B, conditions are more favorable because the fresh gases can sweep the points of the spark plug and keep them clear, and also because of the larger space any burned products retained in the cylinder are not so apt to collect around the plug point.

On some types of engines which are not provided with compression relief, or priming cocks, plugs are sometimes installed, as shown at C. A special fitting, which carries a priming cup at one side, is screwed into the cylinder and the spark plug is fitted to its upper portion. When it is desired to relieve the compression, the valve portion is turned in such a way that a passage is provided from the interior of the fitting to the outer air. At the same time when the valve is in the position shown in illustration, gasoline may be introduced into the cylinder for priming purposes. It is advanced that this method of constructon also provides a simple means of freeing the plug points from oil or particles of carbon if the cock is opened while the engine is running. The high pressure gas which brushes by the points on its way out of the cylinder tends to dislodge any particle of foreign matter which may be present near the spark gap. The same objections apply to this method of mounting as to that illustrated at A.

Spark plugs are made in many different forms and some have been designed with a view of permitting one to see if the charge is being exploded regularly in the cylinder by some form of transparent material for insulation, so that the light produced by the explosion could be seen from the outside of the cylinder. The simplest method of determining if a spark is occurring regularly between the points is to use some form of spark gap which is interposed between the source of current and the plug terminal. A device of this nature is shown at Fig. 185, A. It consists of a body of insulating material which carries in a glass tube two points, which are separated by a slight air space. The eye or hook end is attached to the plug terminal, while the other end is attached to the secondary wire. If the current is passing between the points of the plug, a spark will take

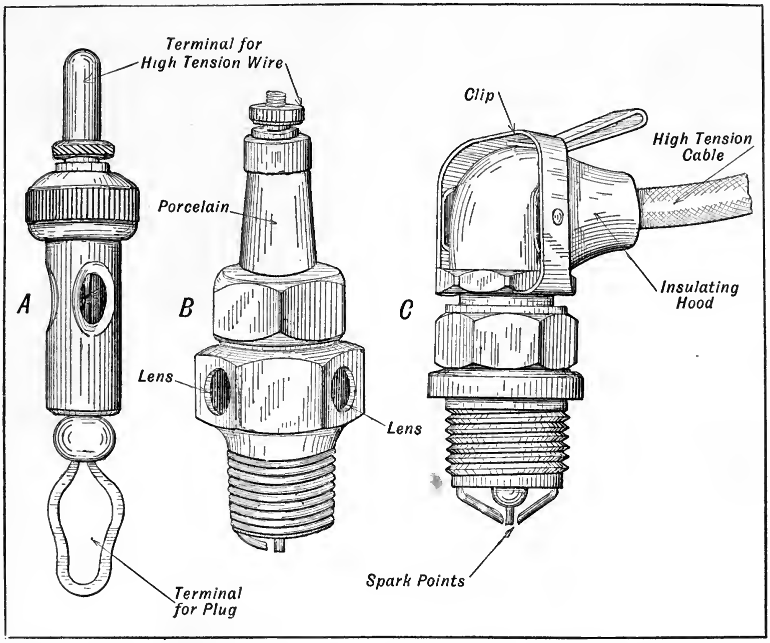


Fig. 185.—Novel Spark Plugs and Accessory Parts. A—Spark Gap Designed to be Placed in Series with Plug Electrode and Current Source. B—Plug Shell with Glass Insets to Show Spark. C—Spark Plug with Waterproof Terminal Cover.

place between the points of the auxiliary spark gap every time one occurs between the points of the plug in the cylinder.

It is claimed that there are certain advantages obtained when a spark gap is used in the circuit, in that the spark in the cylinder is more effective and less liable to be short circuited by particles of foreign matter. At the other hand, others contend that the current must be stronger to jump two gaps than would be required if only the resistance of one was to be overcome. While very popular at one time, the spark gap is of rather doubtful utility and is seldom used at the present time, except as a means of indicating if spark has taken place between the points of the spark plug. It is apt to be somewhat misleading, however, because even if the points of the plug are short circuited and no spark is taking place between the plug points, and yet current is passing to the ground, a spark will continue to take place at the auxiliary spark gap. The device is useful in showing when there is a break or derangement of the wiring or coils.

A form of spark plug having glass bull eyes set into the plug shell or body is shown at Fig. 185, B. These simple lenses are made of specially compounded glass, which has a high resistance to heat and every time an explosion takes place in the cylinder the light resulting causes a flash which is readily seen through the lens. If the flashing is regular it is safe to assume that the cylinder is functioning properly, but should the flashes be intermittent or separated by unequal intervals of time the cylinder is missing explosions.

It is often desirable to have a water-tight joint between the high tension cable and the terminal screw on top of the insulating bushing of the spark plug, especially in marine applications. The plug shown at C is provided with an insulating member or hood of porcelain, which is secured by a clip in such a manner that it makes a water-tight connection. Should the porcelain of a conventional form of plug become covered with water or dirty oil, the high-tension current is apt to run down this conducting material on the porcelain and reach the ground without having to complete its circuit by jumping the air gap and producing a spark. It will be evident that wherever a plug is exposed to the elements, which is often the case in motorcycle or motor-boat service, that it should be protected by an insulating hood which will keep the insulator dry and prevent short circuiting of the spark.

Plugs for Two-Spark Ignition.—On some forms of engines, especially those having large cylinders, it is sometimes difficult to secure complete combustion by using a single-spark plug. If the combustion is not rapid the efficiency of the engine will be reduced proportionately. The compressed charge in the cylinder does not ignite all at once or instantaneously, as many assume, but it is the strata of gas nearest the plug which is ignited first. This in turn sets fire to consecutive layers of the charge until the entire mass is aflame. One may compare the combustion of gas in the gas-engine cylinder to the phenomena which obtains when a heavy object is thrown into a pool of still water. First a small circle is seen at the point where the object has passed into the water, this circle in turn inducing other and larger circles until the whole surface of the pool has been agitated from the one central point. The method of igniting the gas is very similar as the spark ignites the circle of gas immediately adjacent to the sparking point, and this circle in turn ignites a little larger one concentric with it. The second circle of flame sets fire to more of the gas, and finally the entire contents of the combustion chamber are burning.

While ordinarily combustion is sufficiently rapid with a single plug so that the proper explosion is obtained at moderate engine speeds, if the engine is working fast and the cylinders are of large capacity, more power may be obtained by setting fire to the mixture at two different points instead of but one. This may be accomplished by using two sparking plugs in the cylinder instead of one, and experiments have shown that it is possible to gain from twenty-five to thirty per cent in motor power at high speed with two-spark plugs, because the combustion of the gas is accelerated by igniting the gas simultaneously in two places. To fit a double-spark system successfully, one of the plugs must be a double pole member to which the high-tension current is first delivered, while the other may be one of ordinary construction.

A typical double-pole plug is shown in section at Fig. 186, A. In this member two concentric electrodes are used, these being well insulated from each other. One of these is composed of the usual form passing through the center of the insulating bushing, while the other is a metal tube surrounding the tube of insulating material which is wound around the center wire. The current enters the plug through the terminal at the top in the usual manner, but it does not go to the ground because the sparking points are insulated from the steel body of the plug which screws into the cylinder. After the current has jumped the gap between the sparking head and the point, it flows back to the terminal plate at the top, from which it is conducted to the insulated terminal of the usual type plug.

The method of wiring these plugs is shown at Fig. 186, B. The secondary wire from the coil or magneto is attached to the central

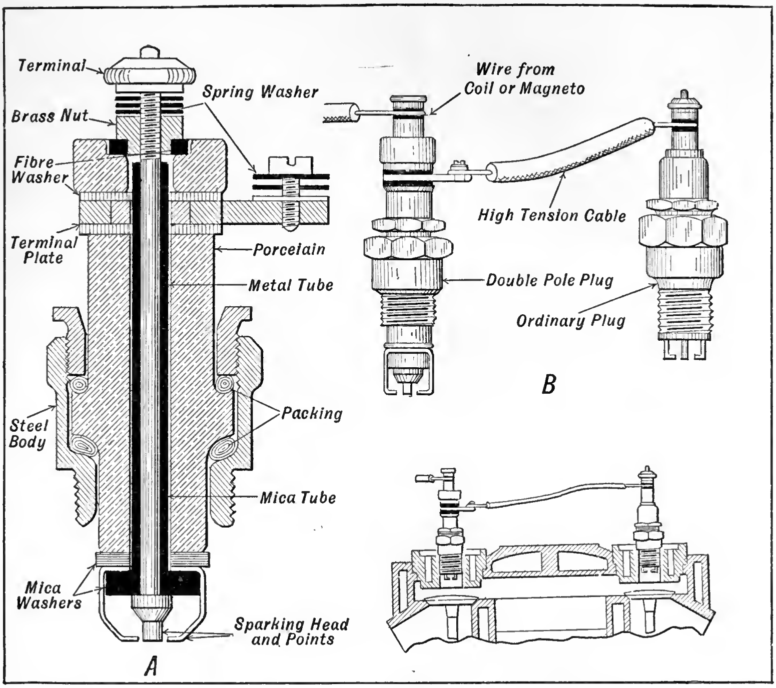


Fig. 186.—Double-Pole Spark Plug and Method of Applying It to Obtain Two Sparks in the Cylinder.

terminal of the double-pole plug, and another cable is attached to the insulated terminal plate below it and to the terminal of the regular type plug. One is installed over the inlet valve, the other over the exhaust valve, if the system is fitted to a T head cylinder. Before the current can return to the source it must jump the gap between the points of the double-pole plug as well as those of the ordinary plug, which is grounded because it is screwed into the cylinder. When a magneto of the high-tension type furnishes the current a double distributor is sometimes fitted, which will permit one to use two ordinary single-pole plugs instead of the unconventional double-pole member. Each of the plugs is joined to an individual distributor, and as but one primary contact breaker or timer is used to determine the time of sparking at both plugs, the ignition is properly synchronized and the sparks occur simultaneously.

Typical Battery Ignition Systems.—The components of typical battery ignition systems may be easily determined by studying the illustrations given at Figs. 187, 188, and 189. The four-cylinder ignition group shown at Fig. 187 depicts the conventional method of wiring

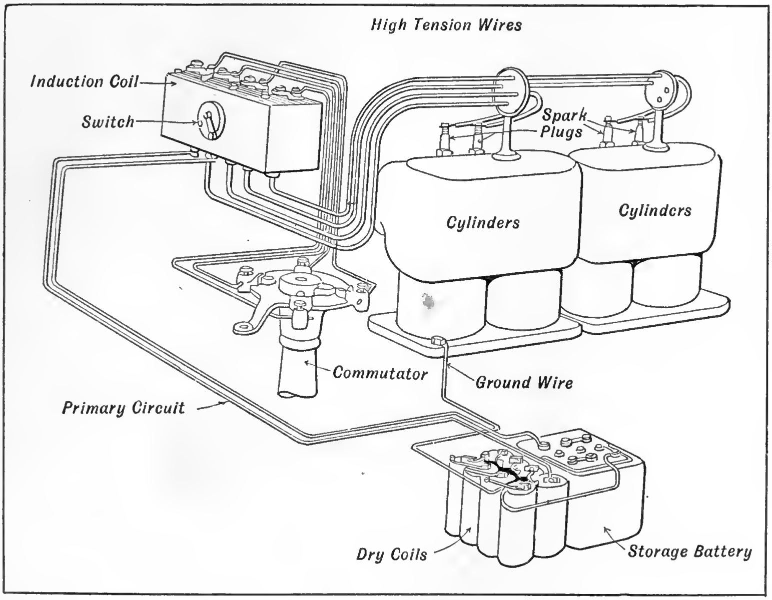


Fig. 187.—Assembly View of Four-Cylinder Ignition Group Showing All Devices and Methods of Wiring.

two sets of batteries, a four-point timer or commutator, and a four-unit induction coil together. It will be seen that eight dry cells are wired together in series and are used as an auxiliary to a six-volt or three-cell storage battery. The negative terminals of the storage battery and dry cell set are coupled together by a short length of wire and are grounded by being attached to the engine base by a suitable conductor. The positive terminals are coupled to the two binding posts under the switch or the coil. The four points of the commutator are attached to the different units of the coil while the secondary wires run from the high-tension terminals on the bottom of the coil to the spark plugs in the cylinders. If the switch lever is placed on one contact button, the current is obtained from the dry cells. If it is swung over to the other side, electricity from the storage battery is utilized.

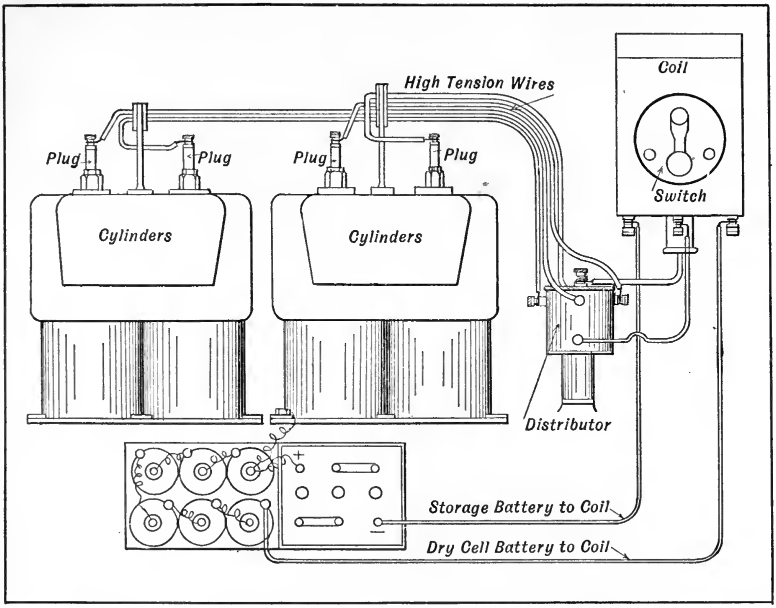


Fig. 188.—Methods of Employing Single Coil to Fire Four Cylinders when Secondary Current is Distributed Instead of Battery Energy.

A typical high-tension distributor system is shown at Fig. 188. Two sources of primary current are provided, one being a six-cell, dry battery, the other a three-cell, or six-volt storage battery. The battery connections are similar to those previously shown and but a single unit coil is needed to fire all cylinders. A single primary wire is attached to the commutator section of the distributor. The secondary wire from the induction coil is joined to the distributing terminal on the top of the distributor, from which it is delivered to the collecting terminals spaced on quarters around the outer periphery of the distributor casing by means of a central distributing segment. Suitable conductors connect the distributor with the spark plugs in the cylinders.

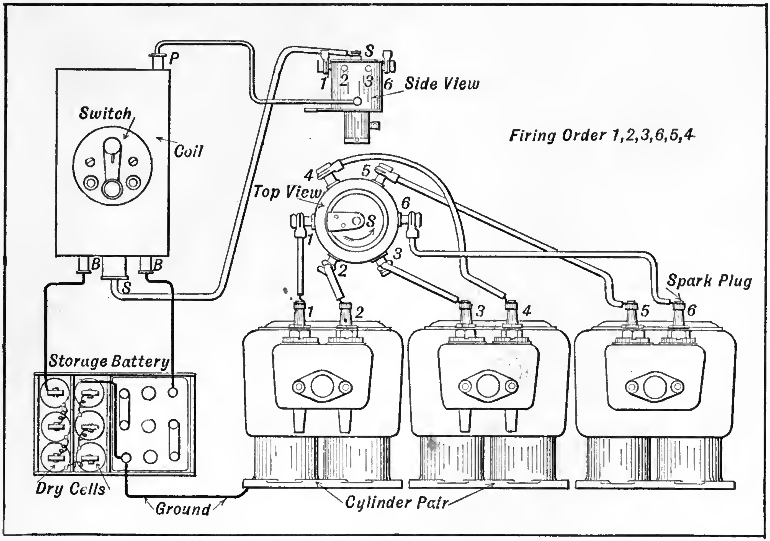


Fig. 189.—Distributor and Coil Ignition Group for Six-Cylinder Motor Showing Order of Firing and Wiring Connections Clearly.

The illustration at Fig. 189 is practically the same as that at Fig. 188, except that a distributor capable of firing a six-cylinder engine is used. If individual unit coils were to be employed, as is the case at Fig. 187, the coil box would contain six units and the primary timer would have six contact points. The wiring would be considerably more complicated than the system outlined.

Features of Low-Tension Ignition System.—Though the low-tension ignition system is seldom used at the present time, a brief description of the method of producing a make-and-break spark is desirable so the reader may gain a thorough knowledge of the methods of ignition the vogue. In order to obtain a spark in the cylinder of any engine, it is necessary that there be a break in the circuit and that this break or interruption be inside of the combustion chamber. The igniter plate used is different in construction from the spark plug forming part of the high-tension system, as the break is made by moving contacts which serve to time the spark as well as produce it.

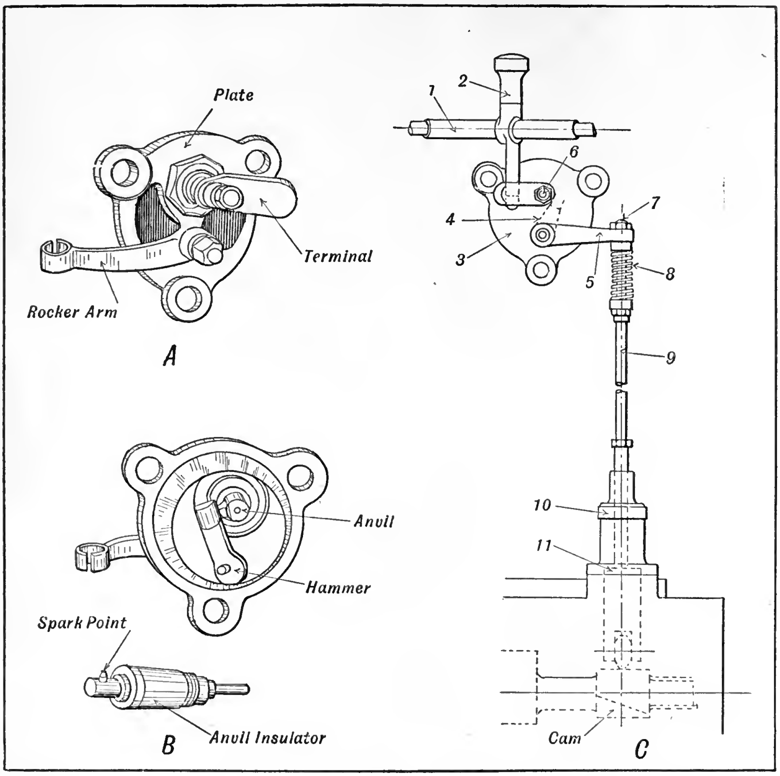


Fig. 190.—Low-Tension Ignition Plate by which Spark is Produced in Some Locomobile Engine Cylinders. A—External View Showing Rocker Arm. B—Interior View Depicting Contact Points. C—Method of Operation.

A typical igniter is shown at A and B, Fig. 190. It consists of a drop-forged plate approximately triangular in form which has a conical ground surface to fit a corresponding female member in the combustion chamber. It is secured by three bolts to a corner of the cylinder close to the inlet valve so the contact points will be traversed by the gases entering from the carburetor. As shown at B, the fixed contact point is called the anvil, while the movable or rocking member is called the hammer. The anvil is insulated from the igniter plate by a bushing of mica or lava, and the hammer alternately makes and breaks contact with the anvil. The method of actuating the hammer by a rocker arm is clearly shown at C. The rocker arm 5 is in the form of a short lever ending in a slotted opening which is connected to the top of the vertical lifter rod 9. This is actuated by a cam on the inlet valve cam shaft which raises the valve plunger **11** in the guide bushing 10. When the lifter rod moves upward the contact point on the hammer inside of the cylinder comes into contact with the platinum point on the anvil and closes the circuit. When the igniter cam reaches the proper point for igniting the charge the lifter rod 9 falls and as the action is quickened by a spring at the bottom of the lifter rod the hammer arm 4 is separated from the contact point on the anvil 6 and a spark takes place as the points are pulled apart.

The coil used when batteries are employed to furnish the current is a simple form. It is a winding of comparatively coarse wire around a core composed of a bundle of soft iron wire. The battery current is intensified to a certain extent by the self-induction of one layer of wire upon the others, and when contact is broken a brilliant spark occurs between the points of the igniter plate. Batteries are seldom used for regular service on the low-tension system because the demands are too severe.

One of the advantages of this system is that the wiring is extremely simple, as will be seen by consulting the diagram of the low-tension ignition system illustrated at Fig. 191. In this both a low-tension magneto and set of batteries are provided, the former being used for regular ignition while the latter are carried for emergency service. A simple form of magneto will serve any number of cylinders because the insulated terminals of the igniters are joined together by a simple conductor or bus bar. A wire from the magneto terminal is joined to one side of the switch, while the other side of the switch is coupled to the coil which is carried in the battery box. A short wire connects the top of the switch lever with the bus bar.

If the switch lever is swung to the left, the magneto produces the current for the igniters, and if the switch lever is placed on the button at the right, the current supply is taken from the batteries. The dry

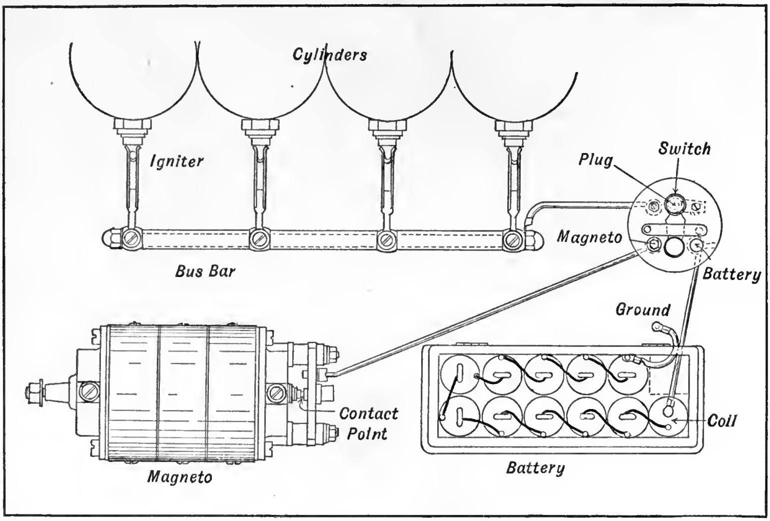


Fig. 191.—Low-Tension Ignition System for Four-Cylinder Motor Utilizes Battery and Magneto for Current Production. Note Simple Wiring—All Conductors Conveying Low-Tension Current.

cells are joined together in series connection, one pole being joined to a coil terminal, the other being grounded. The coil and the igniter plates are in series with the batteries and the current is returned to the ground through the rocker arm, which is a metallic contact with the igniter plate.

The disadvantage which has militated against the general use of the make-and-break system of ignition is that it is very difficult to obtain synchronized spark after the mechanism had become worn, and unless the igniter plates were kept in perfect adjustment the spark time would vary and the efficiency of the engine would be lowered. As the moving electrodes operate under extremely disadvantageous conditions it is difficult to prevent rapid wear of the rocker arm bearing at the igniter plate and consequent leakage of gas results.

Owing to the multiplicity of joints in the operating mechanism it is difficult to secure regular action without backlash or lost motion.

With a high-tension system there are no moving parts inside of the cylinder and it is not difficult to maintain a tight joint between the plug body and the cylinder head. The timer mechanism which is employed when batteries and coils are utilized to furnish the current is a comparatively simple device which is not liable to wear because it can be easily oiled and has a regular rotating movement which can operate without getting out of time much better than the reciprocating parts of the make-and-break mechanism. When a direct high-tension magneto is used the system is not much more complicated as far as wiring is concerned than a low-tension group, and as the ignition is more reliable it is not strange that jump spark or high-tension ignition is almost generally used in automobile practice.

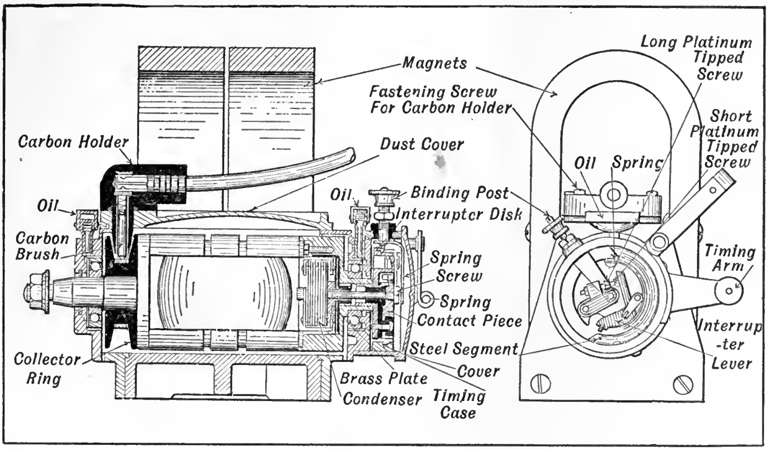


Fig. 192.—Simple High-Tension Magneto for One-Cylinder Ignition. A Complete Apparatus Comprising Source of Current and Timing Device as Well.

Magneto Generator Construction.—The magneto is a simple form of dynamo and a mechanical generator of electricity in which permanent magnets are used to produce the magnetic field and between which the armature revolves. The permanent magnets are called "field magnets" and at their ends are provided cast-iron shoes which form the walls of the armature tunnel and which are known as pole pieces. A typical magneto adapted for single-cylinder ignition is shown in section at Fig. 192. It consists of two compound horseshoe magnets attached to the pole pieces which collect and concentrate the magnetism upon the armature. The armature is shuttle-shaped and carries a double winding of wire which consists of two coils, one of coarse, the other of fine conductor. The armature is attached to end pieces which carry shafts and the whole assembly revolves on annular ball bearings. An ebonite or hard rubber spool is carried at one end while the condenser is housed at the other. The make-and-break mechanism is partly carried by an oscillating casing and the revolving member is turned from the armature shaft.

The current generated in the coil is delivered to a metal ring on the ebonite spool from which it is taken by a carbon brush and delivered directly to the spark plug. Every time the contact points in the make-and-break devices become separated, a current of high potential passes through the wire attached to the spark plug and produces a spark between the points. The magneto is the simplest and most practical form of ignition appliance as it is self-contained and includes the current generator and the timing device in one unit. In the one-cylinder form shown all connections are made inside of the device and but one wire leading to the spark plug is necessary to form the external circuit.

A magneto employed for multiple-cylinder ignition is not much more complicated than that used for single-cylinder service, the only difference being that a different form of cam is provided in the breaker box and that a secondary distributor is added to commutate the current to the plugs in the various cylinders. The distributor consists of a block of insulating material fixed to the magnets which carries as many segments as there are cylinders to be fired. A central distributing arm or segment is driven from the armature shaft by means of gearing, and is employed to distribute the high-tension current to the spark plugs. The spacing of the distributor segments does not differ materially from that of the battery timers previously described.

Various distributor forms used on magnetos are shown at Fig. 193. That at A is employed for a double opposed cylinder motor and the contacts are separated by a space of 180 degrees. When a three-cylinder engine is used, as is sometimes the case in the two-cycle forms, the distributor segments are separated by distances of 120 degrees.

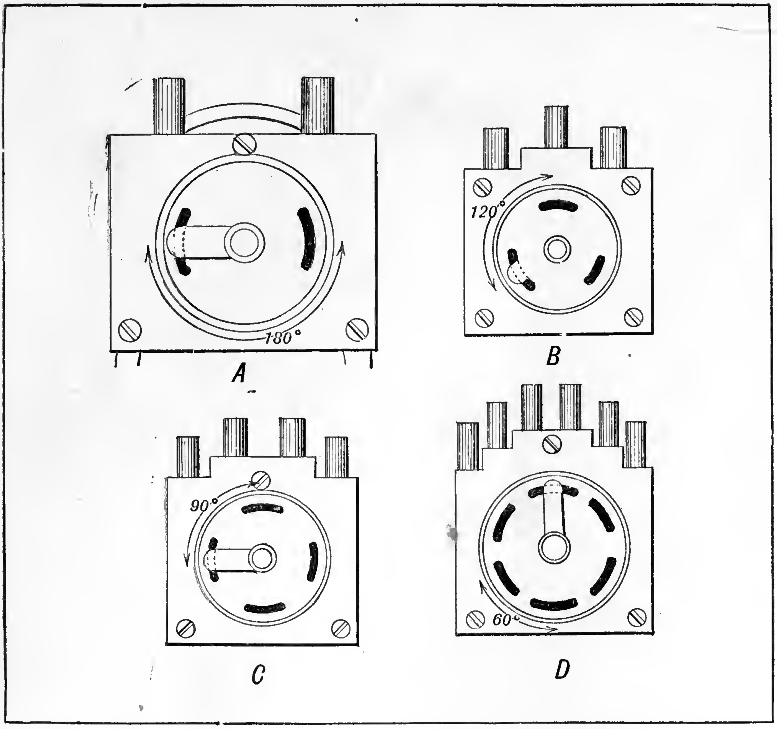


Fig. 193.—How Distributor Contacts are Spaced on Two-, Three-, Four- and Six-Cylinder Magnetos.

If the distributor is used on a four-cylinder motor the segments are spaced 90 degrees apart, as shown at C. To fire a six-cylinder motor, six segments must be used and they are placed 60 degrees apart, as indicated at D.

The speed at which the armature of the magneto turns also varies with the number of cylinders. One- and two-cylinder forms turn at cam-shaft speed. The three-cylinder types when applied to a four-cycle engine turn at three quarters the crank-shaft speed. The four-cylinder magneto armature is driven at crank-shaft speed, while that of the six-cylinder forms turn at one and one half times crank-shaft speed. When used on two-cycle motors, the speeds given for four-cycle engines of the same number of cylinders should be doubled.

The important parts of a four-cylinder form of high-tension magneto are shown at Fig. 194, which is a view of a partially dismantled device. The armature assembly and one of the end plates by which it is supported are shown at the extreme left. Attached to the end of the armature shaft are the distributor drive pinion and the ebonite spool which carries the collector ring. The timer case and interrupter assembly are shown at the extreme right. Above it the distributor case is clearly depicted. When the device is assembled the end of the armature shaft protrudes through the housing at the lower part of the magnet assembly which is shown in the center of the group, with the end plate which carries the distributor gear and disk and one end of the armature in place. The distributor gear serves to drive a hard rubber plate in which the distributor segment is imbedded. When the distributor case is screwed in place, the carbon brushes, which are spaced around the interior of the distributor case, collect current from the revolving distributor segment and lead it to the spark plugs by suitable cables which run from the terminals at the top of the distributor casing.

Two systems of high-tension magneto ignition are used, one termed the true high-tension system, in which a current of high potential is delivered directly from the armature; the other is the transformer coil system, so termed because the current produced by the armature winding is of low tension and must be stepped up or increased in value before it is delivered to the spark plug by an induction coil similar in construction to that needed in battery-ignition systems. In the former apparatus the high-tension current is produced by means of a secondary winding on the armature itself, and as the whole apparatus is self-contained it is much more compact and simpler to install than those which need a separate transformer coil.

The simplified wiring system of a true high-tension magneto is shown at Fig. 195. The armature carries two windings, one indicated by the heavier lines at the bottom called the "primary"; the other, composed of finer conductor, is known as the "secondary." One end

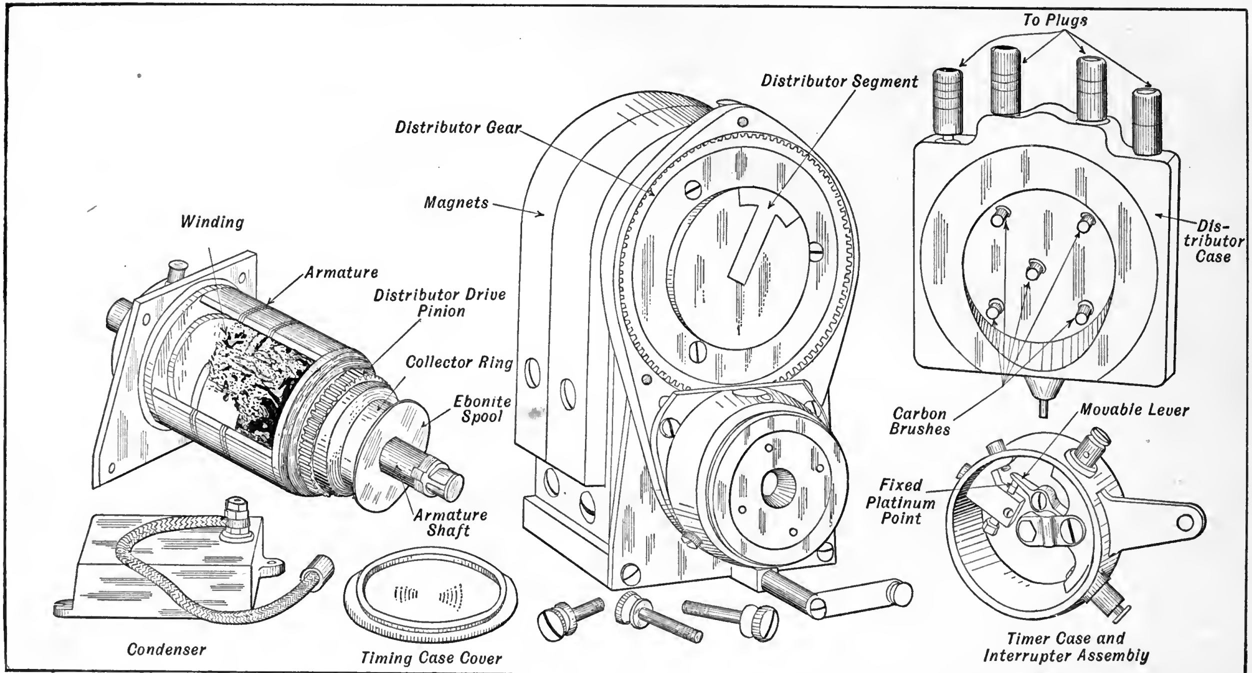


Fig. 194.—Partially Dismantled Four-Cylinder Magneto, Showing Important Parts of Current-Producing and Distributing Elements.

of the primary winding is grounded, the other is joined to the fixed contact screw of the contact breaker. This end is also joined to one end of the secondary winding and the free end of the secondary winding is attached to the collector ring carried by the ebonite spool. When the contact points separate, a current is induced in the primary

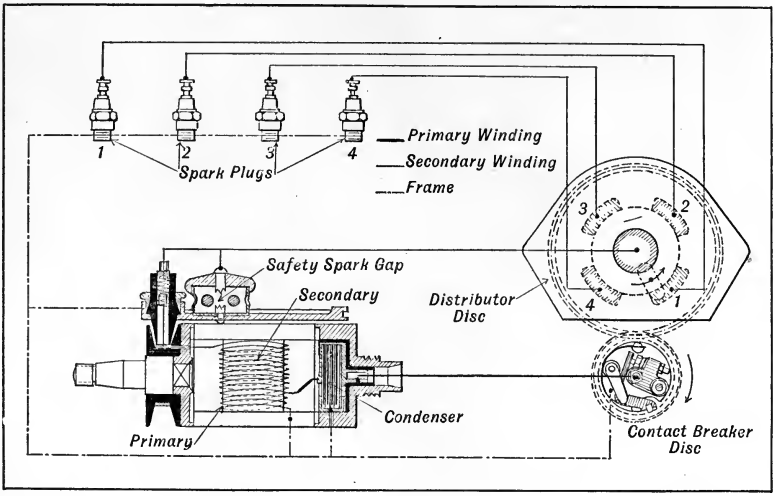


Fig. 195.—Simple Wiring Scheme when Four-Cylinder Magneto is Utilized for Gas-Engine Ignition. Magneto Members Shown Separate to Facilitate Explanation of Principles of Operation.

and secondary windings and is delivered to the center terminal of the distributor disk by the carbon brush which bears against the collector ring.

The various segments of the distributor are connected to the spark plugs in the cylinders, and every time the contact points separate a spark will be produced at one of the plugs because the revolving distributor brush will be in contact with one of the distributor segments. A cross-section view of the Bosch high-tension magneto is shown at Fig. 196 and the important parts are clearly shown. As the internal connections are very similar to those shown diagrammatically at Fig. 195, the same description given of the course of current in the former applies equally well to the latter.

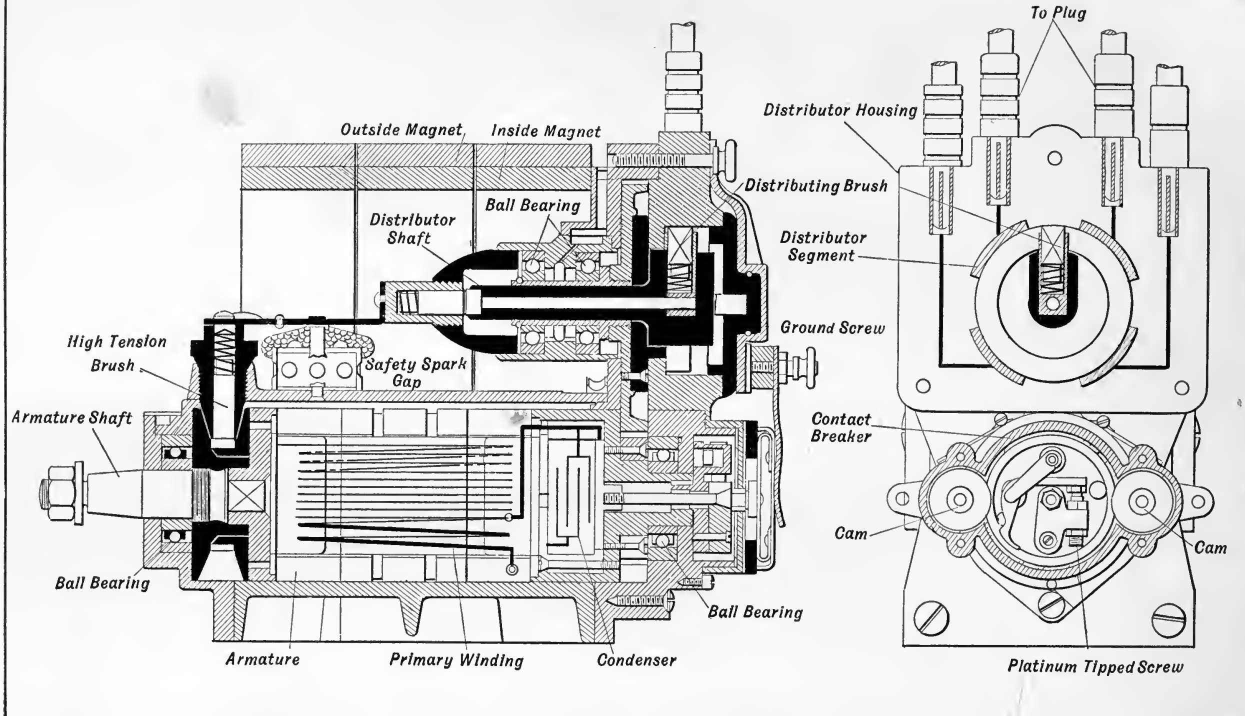


Fig. 196.—Side Sectional View of Bosch High-Tension Magneto Shows Disposition of Parts. End Elevation Depicts Arrangement of Interruptor and Distributor Mechanism.

The wiring of a four-cylinder magneto which employs a transformer coil is shown at Fig. 197. A set of batteries is provided to furnish current for starting, as it is sometimes difficult to turn the motor sufficiently fast by hand to generate the proper amount of magneto current to insure prompt starting. The high-tension wire

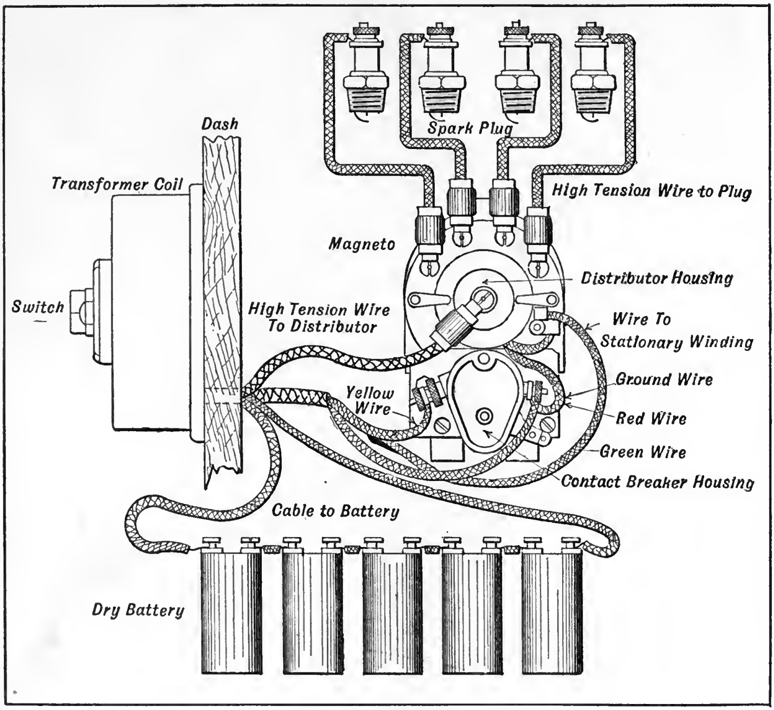


Fig. 197.—Wiring Diagram Outlining Method of Combining Magneto and Transformer Coil to Form Device for Four-Cylinder Ignition.

from the spark coil or transformer is led to the center of the distributor and the current is commutated to the plugs just as though the high-tension current had been produced in the magneto itself instead of in the transformer.

The Connecticut magneto, which is a transformer coil type, is shown in longitudinal section and end elevation at Fig. 198. In this,

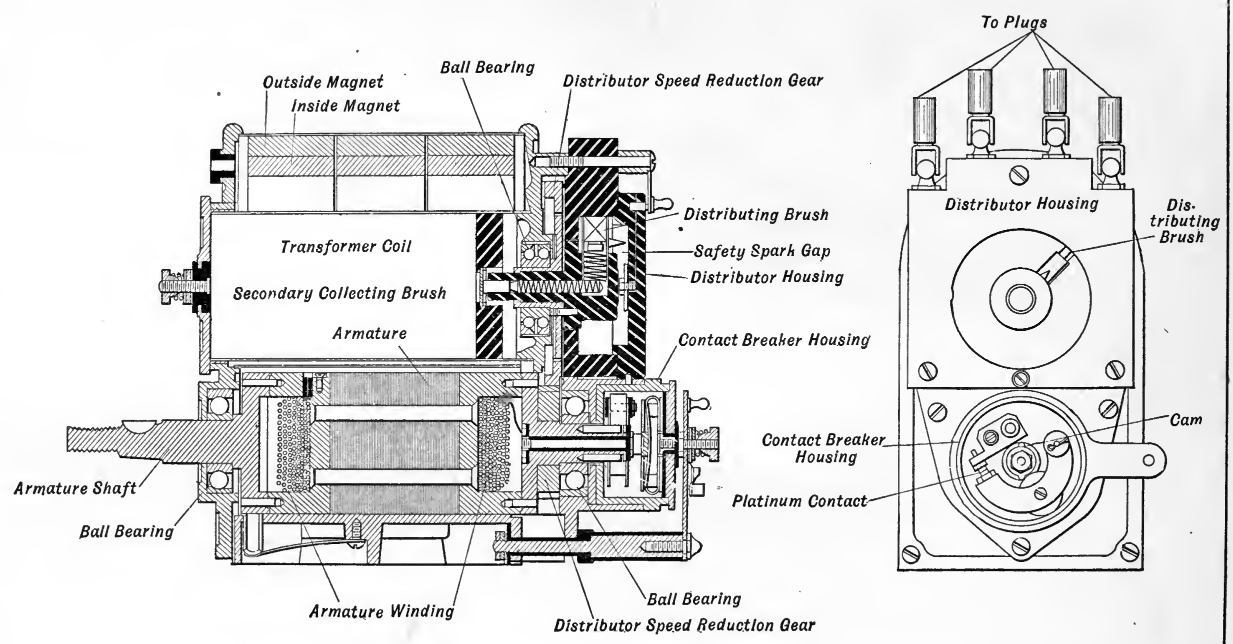


Fig. 198.—Defining Construction of Connecticut Magneto, a Form in which Transformer Coil is Placed Between Magnets Above Armature Tunnel.

the transformer coil is mounted between the magnets above the armature tunnel and the secondary current is applied directly to the distributing brush by means of a secondary collecting member which bears against a suitable terminal in the bottom of the coil casing. With this magneto the wiring is as simple as it would be with the true high-tension form and only five wires are needed in the external

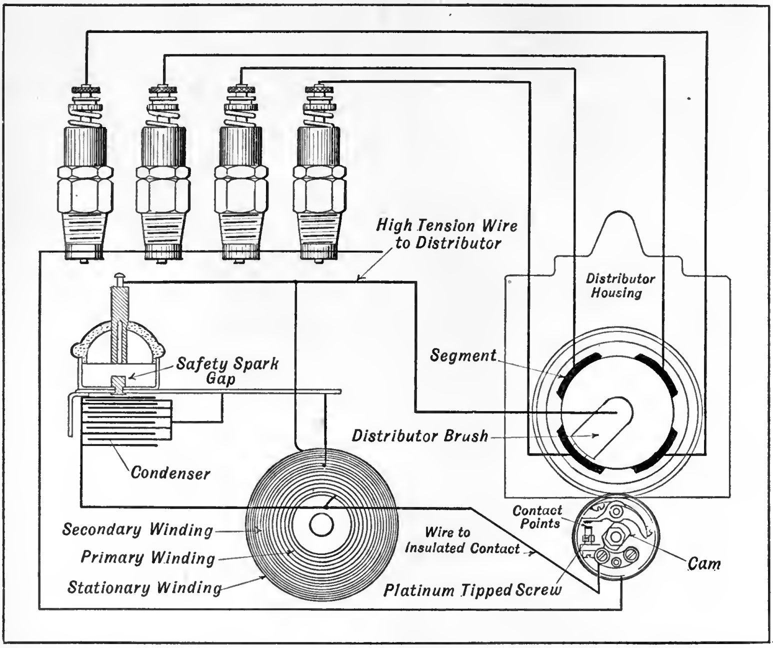


Fig. 199.—Showing Application of High-Tension Principle in K.W. Four-Cylinder Magneto.

circuit. Of these, four secondary leads run direct from the distributor to the plug while the remaining one is a primary ground wire having a switch in circuit through which the primary coil current may be grounded instead of going to the transformer coil, thus stopping the motor.

All magnetos do not employ a revolving winding. Some utilize a stationary coil of wire and use rotating inductor members to cause the lines of magnetic force to flow through the wire and generate a

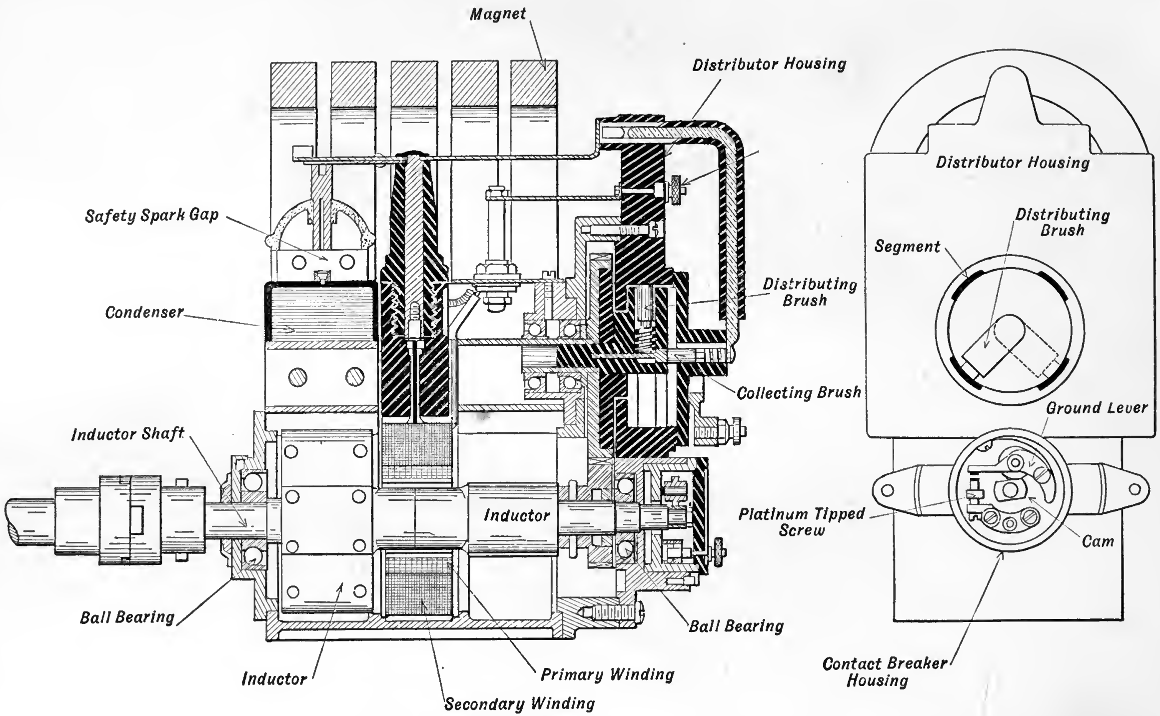


Fig. 200.—K.W. High-Tension Magneto, a Distinctive Form Utilizing Stationary Winding and Revolving Inductor Elements to Produce Current for Ignition.

current therein. A simplified wiring diagram of the K.W. magneto, which is an igniter of this type, is shown at Fig. 199, while a sectional view of the device itself is presented at Fig. 200. The stationary coil is composed of two windings, a primary and a secondary, and is mounted in the center of the device so that the rotary inductor shaft passes through it, one inductor being placed at each side of the stationary coil. The secondary wire passes through the insulated electrode through a bridge or strap member which is connected at one end to the spark gap and at the other to a bent conductor which conveys the current to a revolving distributor arm.

When the contact points are separated by the cam a current of electricity is induced in the primary coil and transformed to a high-tension current in the secondary winding and is delivered to the spark plugs by the conventional form of distributor. Except for the stationary winding and the use of inductor pieces to reverse the lines of magnetism through the coil, the construction does not differ from the forms previously described. It is advanced that the stationary winding offers some advantages inasmuch as brushes are not required to collect the primary current.

The function of the safety spark gap is to take care of any excess current which might damage the insulation of the winding by allowing it to go to the ground. The air gap between the points has high enough resistance so that the spark will not jump it under normal conditions, but should the voltage become suddenly increased in value, as might be the case if one of the plug wires became disconnected, it will leap this gap in preference to overcoming the resistance of the insulation of the winding. The purpose of the condenser in a magneto is the same as that used in a coil, i. e., it is interposed in the primary circuit in such a way that it is in shunt connection with the contact-breaker points and absorbs any current which would tend to produce excessive sparking.

Application of Typical Magneto Forms.—Some of the leading forms of American magnetos are shown at Fig. 201. That at A is the Heinze device and differs from the conventional form in that magnets of round section are used instead of the conventional horseshoe magnets of rectangular cross section. The form shown at B is the Kingston magneto, which is used in connection with a transformer coil. The Connecticut, which has been previously shown in section at Fig. 198, is depicted at C. The double distributor form intended to be used in connection with two-spark ignition systems shown at D is a Splitdorf design and should be used with a separate transformer coil.

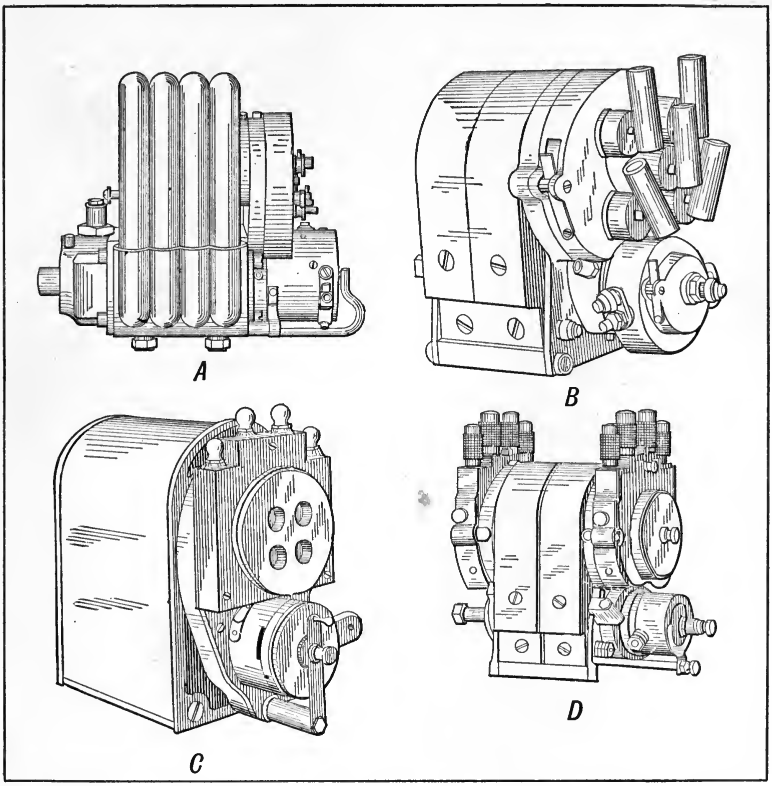


Fig. 201.—Typical American Magneto Forms. A—Heinze Machine with Round Section Field Magnets. B—Kingston Magneto for Dual Ignition. C—Clean-Cut Design of Connecticut Device. D—Splitdorf Double Distributor Form Designed for Two-Spark Ignition Systems.

The usual method of installing a magneto is to place it on a bracket fastened to the engine base so the contact breaker and distributor will be handy for immediate inspection or adjustment. It is desirable to place the device on the inlet side of the engine and as far away from the exhaust piping as possible because the excess heat which exists at this point is liable to injure the insulation of the windings. Methods of installation which are typical of conventional practice are shown at Fig. 202. At A the magneto is placed on a cast

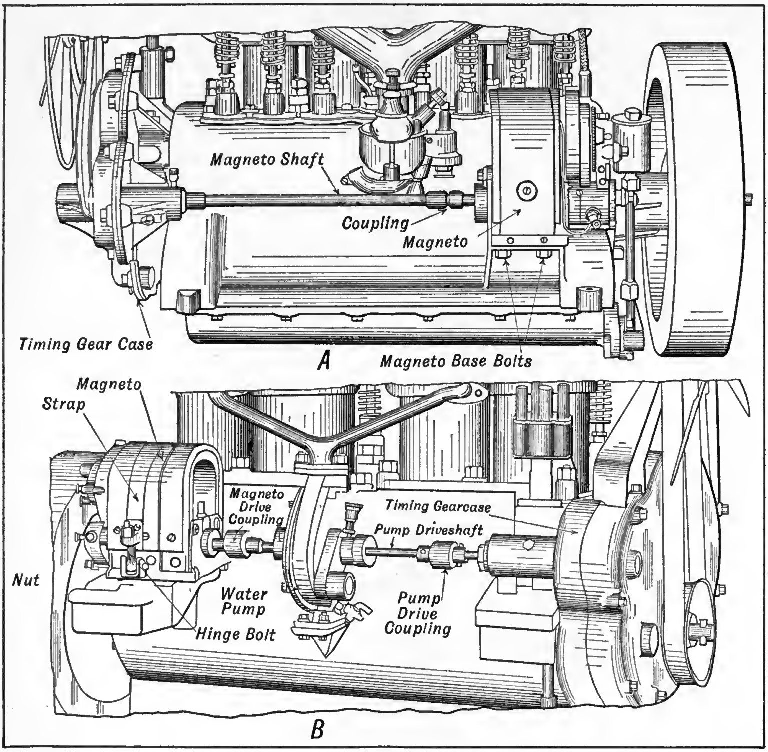


Fig. 202.—Conventional Methods of Placing and Driving Magneto Generators. A—System Used on Regal Engine. B—Magneto is Driven from Pump-Shaft Extension on Velie Motors.

bracket formed integral with the top half of the engine base and is driven from the timing case at the front of the engine by a length of shaft. At B the magneto is also housed at the rear end and is carried on a base plate formed integrally with one of the crank-case supporting arms. The drive is by an extension of the pump shaft, that member being driven by suitable gearing in the cam-shaft timing gear casing.

Gear drive is the best method of driving a magneto armature and direct spur-gear connection is better than either bevel or spiral gear trains because it is the best wearing form of gearing. Silent chains may be used for driving if some form of adjustment is provided to compensate for chain stretch. When a magneto is driven by a shaft, as shown at Fig. 202, A and B, it is customary to provide some sort of a universal joint or Oldham coupling between the armature and the driving member in order that any inaccuracies in alignment of the driving shaft will not stress the ball bearings supporting the armature. It is desirable to protect the instrument from oil or water by placing it in a case of fiber or leather, and in modern types the contact breaker and distributor housings are closed by easily removed and yet practically dust-tight coverings.

Metallic or carbon particles and dirty oil may cause internal short circuiting and it is desirable to have the contact-maker case and the distributor cover arranged in such a way that they may be easily reached for cleaning. Modern magnetos are usually secured in some way that will permit a ready removal. In that shown at A, Fig. 202, a number of through bolts are screwed from the under side of the bracket into the magneto base and it is necessary to remove these before the magneto can be lifted off its support. The method shown at Fig. 202, B, is preferable as the ignition device may be removed from the base by slackening one nut on the hinge bolt which keeps the metallic strap tight, thus holding the magneto in place.

Various other methods of utilizing strap members are shown at Fig. 203. In that shown at A the strap is made in two pieces and is held together at the top by a clamp bolt. The method of securing a magneto, shown at B, is practically the same, except that the retention member is a small knob which can be easily turned by the hand. At C the strap encircles the magneto completely and is held in place by a single nut under the bracket. A modification of this method is depicted at D. The strap, in this instance, is just bent over the arch of the magnets and held in place by the long swinging bolt which is hinged at the bottom of the magneto.

One of the simplest methods of driving a magneto is that shown at Fig. 204, which is a bottom view of the Ford engine case. The stationary coils of the magneto are attached to the crank case, and the

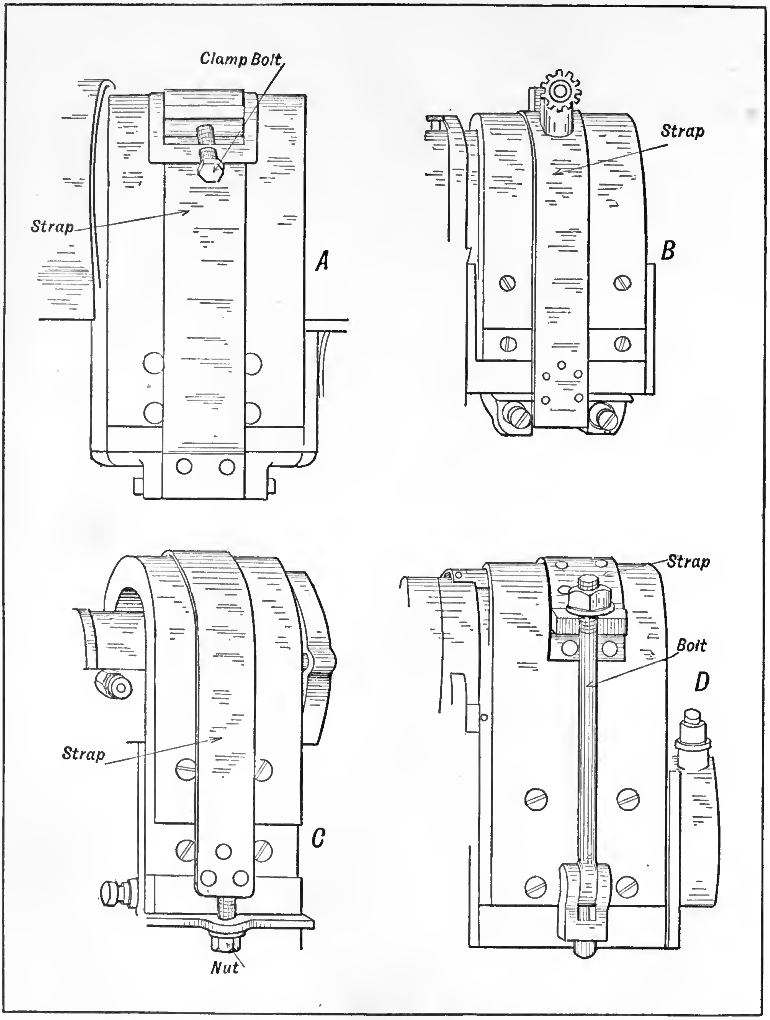


Fig. 203.—Simple Methods of Holding Magnetos in Place on Engine Base to Permit of Easy Removal of Apparatus when Desired.

revolving magnets rotate with the fly wheel, which in turn is securely attached to the crank shaft. With this form of drive there can be no interruption in current generation and there are no gears, chains, or other connections to wear and produce noise or interfere with generation of current.

When the magneto was first introduced it was looked upon with suspicion by the motoring public. Therefore some designers compromise and furnish two separate systems, one composed of a magneto, the other an auxiliary group comprising a battery, timer and coil, which supply the current to a set of spark plugs distinct from those supplied from the magneto. It was found difficult with some types of magnetos to start the engine directly from magneto current so the battery outfit was depended upon for starting the engine as well as emergency service. The parts of the modern high-tension magneto have been simplified and strengthened and as the various parts may be removed easily and replaced without trouble and special care taken so the adjustments and cleaning necessary may be easily understood by the layman there is very little liability at the present time of a magneto giving out without warning.

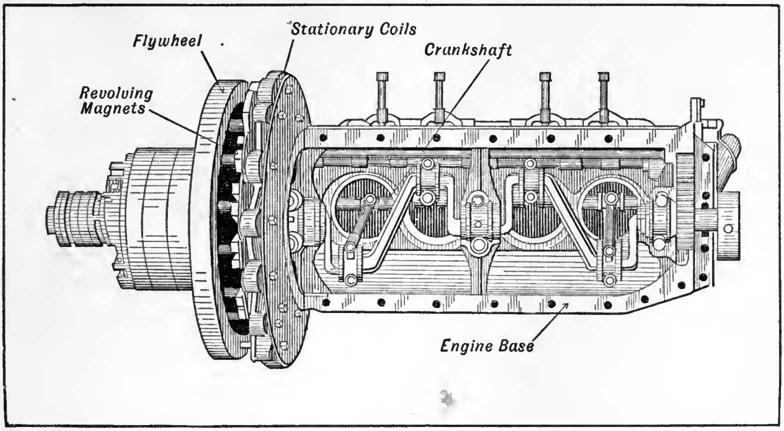


Fig. 204.—The Ford Magneto is Integral with Engine Base, and Revolving Magnets are Attached to Fly Wheel. Thus Direct Drive from Crank Shaft is Possible without Gears.

A typical magneto ignition system used in connection with a battery set is shown at Fig. 205. Six dry cells are used to supply the current and a conventional four-point timer commutates the battery

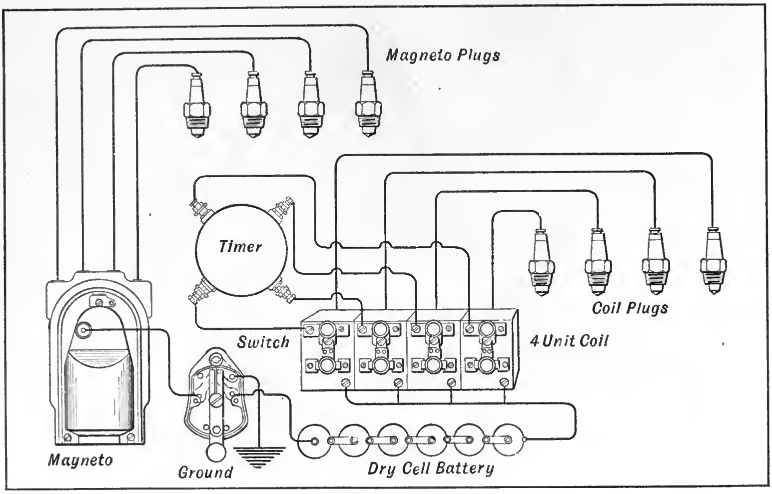


Fig. 205.—Double Ignition System Utilizing Battery and Induction Coil Group for Starting and Emergency Service and Pittsfield High-Tension Magneto as the Main Ignition System.

current to the four individual units of the coil box, which in turn delivers secondary current to the plugs. When the switch is thrown to one side the magneto system is utilized. When the contacts are reversed the battery system furnishes the ignition energy. The parts are shown arranged in diagram form so that the wiring may be easily followed and the relation of the various parts to each other definitely ascertained. The methods of wiring typical double systems are further exemplified by diagram shown at Fig. 206.

Connections of parts comprising the Bosch dual ignition system are shown at Fig. 207. With this method but one set of spark plugs is needed as the secondary distributor of the magneto is utilized to distribute the high-tension current obtained either from the magneto armature or the battery and coil system. A separate timer is used to interrupt the battery current, and the coil carried on the dash is of such a nature that depressing a button will bring a vibrator in circuit and throw a constant stream of sparks across the air gap of the spark plug in the cylinder about to fire. This will start the engine, if a four- or six-cylinder form, without cranking when conditions are favorable. Ordinarily when running on the battery system

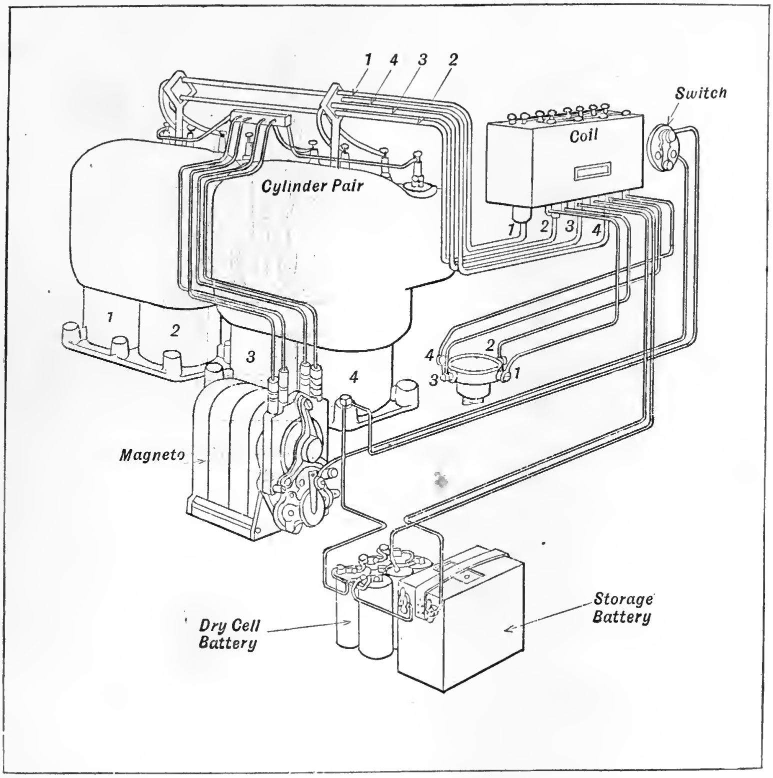


Fig. 206.—Practical Application of Double Ignition System to Four-Cylinder Power Plant.

the coil vibrator is not used, a single spark taking place between the points of the spark plug. The various connections are clearly shown in illustration and further description would be superfluous.

When a magneto is installed some precautions are necessary relating to wiring and also the character of the spark plugs employed. The conductor should be of good quality, have ample insulation and be well protected from accumulations of oil which would tend to decompose rubber insulation. It is customary to protect the wiring by running it through the conduits of fiber or metal tubing lined with

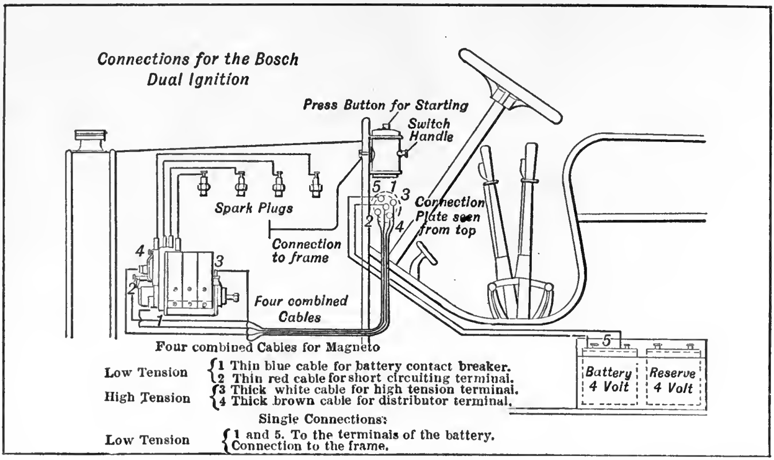


Fig. 207.—Method of Applying Bosch Dual Ignition System to Conventional Four-Cylinder Power Plant.

insulating material. Multiple strand cables should be used for both primary and secondary wiring and the insulation should be of rubber at least $\frac{3}{16}$ inch thick.

The spark plugs commonly used for battery and coil ignition cannot always be employed when a magneto is fitted. The current produced by the mechanical generator has a greater amperage and more heat value than that obtained from transformer coils excited by battery current. The greater heat may burn or fuse the slender points used on some battery plugs and heavier electrodes are needed to resist the heating effect of the more intense arc. While the current has greater amperage it is not of as high potential or voltage as that commonly produced by the secondary winding of an induction coil, and it cannot overcome as much of a gap. Manufacturers of magneto plugs usually set the spark points about $\frac{1}{64}$ of an inch apart. The most efficient magneto plug has a plurality of points so that when the distance between one set becomes too great the spark will take place between one of the other pairs of electrodes which are not separated by so great an air space.

Expert motorists championed the cause of mechanical generators of electricity some time ago, but it is only within the past year or two that the public demand for these devices impelled manufacturers of motor cars to supply them as regular equipment on their cars.

CHAPTER VII

Reason for Lubrication of Mechanism—Lubricants and their Derivation—Methods of Supplying Oil—Typical Lubrication Systems Outlined—Theory and Functions of Cooling Systems—Water-Cooling Methods Explained—Elements of Simple Circulating System—Forced Circulation and Apparatus—Thermosyphon-Cooling Methods—Air-Cooling Systems.

THE importance of minimizing friction at the various bearing surfaces of machines to secure mechanical efficiency is fully recognized by all mechanics, and proper lubricity of all parts of the mechanism is a very essential factor upon which the durability and successful operation of the motor car power plant depends. All of the moving members of the engine which are in contact with other portions, whether the motion is continuous or intermittent, of high or low velocity or of rectilinear or continued rotary nature, should be provided with an adequate supply of oil. No other assemblage of mechanism is operated under conditions which are so much to its disadvantage as the motor car, and the tendency is toward a simplification of oiling methods so that the supply will be ample and automatically applied to the points needing it.

In all machinery in motion the members which are in contact have a tendency to stick to each other and the very minute projections which exist on even the smoothest of surfaces would have a tendency to cling or adhere to each other if the surfaces were not kept apart by some elastic and unctuous substance. This will flow or spread out over the surfaces and smooth out the inequalities existing which tend to produce heat and retard motion of the pieces relative to each other.

A general impression which obtains is that well machined surfaces are smooth and while they are apparently free from roughness and no projections are visible to the naked eye, any smooth bearing surface, even if very carefully ground, will have a rough appearance if examined with a magnifying glass. An exaggerated condition to illustrate this point is shown at Fig. 208. The amount of friction will vary in proportion to the pressure on the surfaces in contact and will augment as the loads increase, the rougher surfaces will have more friction than smoother ones and soft bodies will produce more friction than hard substances.

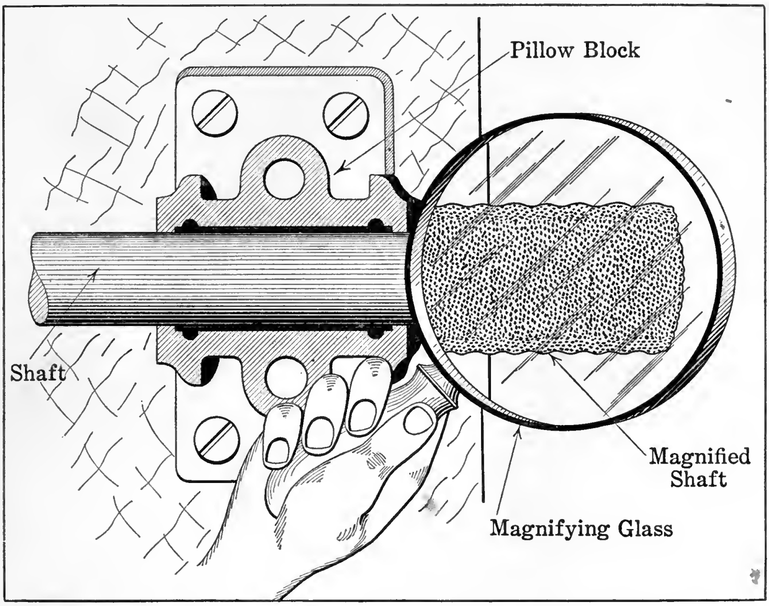


Fig. 208.—Showing Use of Magnifying Glass to Demonstrate that Apparently Smooth Metal Surfaces May Have Minute Irregularities which Produce Friction.

Friction is always present in any mechanism as a resisting force that tends to retard motion and bring all moving parts to a state of rest. The absorption of power by friction may be gauged by the amount of heat which exists at the bearing points. Friction of solids may be divided into two classes, sliding friction, such as exists between the piston and cylinder, or the bearings of a gas engine and rolling friction, which is that present when the load is supported by ball or roller bearings or that which exists between the tires or the driving wheels and the road. Engineers endeavor to keep friction losses as low as possible and much care is taken in all modern automobiles to provide adequate methods of lubrication, or anti-friction bearings at all points where considerable friction exists.

Theory of Lubrication.—The reason a lubricant is supplied to bearing points will be easily understood if one considers that these elastic substances flow between the close fitting surfaces, and by filling up the minute depressions in the surfaces and covering the high spots act as a cushion which absorbs the heat generated and takes the wear instead of the metallic bearing surface. The closer the parts fit together the more fluid the lubricant must be to pass between their surfaces and at the same time it must possess sufficient body so that it will not be entirely forced out by the pressure existing between the parts.

Oils should have good adhesive, as well as cohesive, qualities. The former are necessary so that the oil film will cling well to the surfaces of the bearings; the latter, so the oil particles will cling together and resist the tendency to separation which exists all the time the bearings are in operation. When used for gas-engine lubrication the oil should be capable of withstanding considerable heat in order that it will not be vaporized by the hot portions of the cylinder. It should have sufficient cold test so that it will remain fluid and flow readily at low temperature. Lubricants should be free from acid, or alkalis, which tend to produce a chemical action with metals and result in corrosion of the parts to which they are applied. It is imperative that the oil be exactly the proper quality and nature for the purpose intended and that it be applied in a positive manner. The requirements may be briefly summarized as follows:

First—It must have sufficient body to prevent seizing of the parts to which it is applied and between which it is depended upon to maintain an elastic film, and yet it must not have too much viscosity in order to minimize the internal or fluid friction which exists between the particles of the lubricant itself.

Second—The lubricant must not coagulate or gum, must not injure the parts to which it is applied, either by chemical action or by producing injurious deposits, and it should not evaporate readily.

Third—The character of the work will demand that the oil should not vaporize when heated or thicken to such a point that it will not flow readily when cold.

Fourth—The oil must be free from acid, alkalis, animal or vegetable fillers, or other injurious agencies.

Fifth—It must be carefully selected for the work required and should be a good conductor of heat.

Derivation of Lubricants.—The first oils which were used for lubricating machinery were obtained from animal and vegetable sources, though at the present time most unguents are of mineral derivation. Lubricants may exist as fluids, semifluids, or solids. The viscosity will vary from light spindle or dynamo oils which have but little more body than kerosene to the heaviest greases and tallows. The most common solid employed as a lubricant is graphite, sometimes termed "plumbago" or "black lead." This substance is of mineral derivation.

The disadvantage of oil of organic origin, such as those obtained from animal fats or vegetable substances, is that they will absorb oxygen from the atmosphere which causes them to thicken or become rancid. Such oils have a very poor cold test as they solidify at comparatively high temperatures and their flashing point is so low that they cannot be used at points where much heat exists. In most animal oils various acids are present in greater or less quantities, and for this reason they are not well adapted for lubricating metallic surfaces which may be raised high enough in temperature to cause decomposition of the oils.

Lubricants derived from the crude petroleum are called "Oleonapthas" and they are a product of the process of refining petroleum through which gasoline and kerosene are obtained. They are of lower cost than vegetable or animal oil and as they are of nonorganic origin they do not become rancid or gummy by constant exposure to the air and they will have no corrosive action on metals because they contain no deleterious substances in chemical composition. By the process of fractional distillation mineral oils of all grades can be obtained. They have a lower cold and higher flash test and there is not the liability of spontaneous combustion that exists with animal oils.

The organic oils are derived from fatty substances which are present in the bodies of all animals and in some portions of plants. The general method of extracting oil from animal bodies is by a rendering process which consists of applying sufficient heat to liquefy the oil and then separating it from the tissue with which it is combined by compression. The only oil which is used to any extent in gas-engine lubrication that is not of mineral derivation is castor oil. This substance has been used on high-speed racing automobile engines and on aëroplane power plants. It is obtained from the seeds of the castor plant which contain a large percentage of oil.

Among the solid substances which may be used for lubricating purposes may be mentioned tallow, which is obtained from the fat of animals, and graphite and soapstone, which are of mineral derivation. Tallow is never used at points where it will be exposed to much heat, though it is often employed as a filler for greases used in transmission gearing. Graphite is sometimes mixed with oil and applied to cylinder lubrication, though it is most often used in connection with greases in the running gear parts. Graphite is not affected by heat, cold, acids, or alkalis and has a strong attraction for metal surfaces. It mixes readily with oils and greases and increases their efficiency in many applications. It is sometimes used where it would not be possible to use other lubricants because of extremes of temperature. Graphite can be applied to advantage to practically all portions of the motor-car mechanism.

The oils used for cylinder lubrication are obtained almost exclusively from crude petroleum derived from American wells. Special care must be taken in the selection of the crude material, as every variety will not yield oil of the proper quality to be used as a cylinder lubricant. The crude petroleum is distilled as rapidly as possible with fire heat to vaporize off the naphthas and the burning oils. After these vapors have been given off superheated steam is provided to assist in distilling. When enough of the light elements have been eliminated the residue is drawn off, passed through a strainer to free it from grit and earthy matters, and is afterwards cooled to separate the wax from it. This is the dark cylinder oil and is the grade usually used for steam-engine cylinders.

The oil that is to be used in the gasoline engine must be of high quality and for that reason the best grades are distilled in a vacuum that the light distillates may be separated at much lower temperatures than ordinary conditions of distilling permit. If the degree of heat is not high the product is not so apt to decompose and deposit carbon. If it is desired to remove the color of the oil which is caused by free carbon and other impurities it can be accomplished by filtering the oil through charcoal. The greater the number of times the oil is filtered, the lighter it will become in color. The best cylinder oils have flash points usually in excess of 500 degrees F. and while they have a high degree of viscosity at 100 degrees F. they become more fluid as the temperature increases.

The lubricating oils obtained by refining crude petroleum may be divided into three classes:

First—The natural oils of great body which are prepared for use by allowing the crude material to settle in tanks at high temperature and from which the impurities are removed by natural filtration. These oils are given the necessary body and are free from the volatile substances they contain by means of superheated steam which provides a source of heat.

Second—Another grade of these natural oils which are filtered again at high temperatures and under pressure through beds of animal charcoal to improve their color.

Third—Pale, limpid oils, obtained by distillation and subsequent chemical treatment from the residuum produced in refining petroleum to obtain the fuel oils.

Authorities agree that any form of mixed oil in which animal and mineral lubricants are combined should never be used in the cylinder of a gas engine as the admixture of the lubricants does not prevent the decomposition of the organic oil into the glycerides and fatty acids peculiar to the fat used. In a gas-engine cylinder the flame tends to produce more or less charring. The deposits of carbon will be much greater with animal oils than with those derived from the petroleum base because the constituents of a fat or tallow are not of the same volatile character as those which comprise the hydrocarbon oils which will evaporate or volatilize before they char in most instances.

A suitable lubricant for gas-engine cylinders is a pure hydrocarbon oil having a high vaporizing point, about 200 degrees F., a flash point of 430 degrees F., and a fire test of about 600 degrees F. It is fortunate that many brands of good oils may be obtained at the present time and in this connection it is well to state that the best oil is none too good for the motor-car engine cylinders. There is an impression among many motorists of economical tendencies that any oil will answer and that the cheapest is obviously best because it costs less. A point that cannot be too strongly impressed upon all who have machinery of any description in their care is that efficient operation can only be obtained by selecting proper lubricant, and that high quality oils can only be obtained by paying for them. In this application the old adage, "The best is the cheapest in the end," is particularly apropos.

Devices for Supplying Lubricant.—The method of supplying the lubricant will depend largely upon the nature of the part to be oiled as well as the character of the oily medium. The various parts of the internal combustion engine demand continued lubrication and means must be provided which will insure positive supply of lubricant in measured quantities for more or less extended periods. Engine lubricators should be positive in action and not liable to be affected by varying weather conditions. The lubricant should not be supplied in excess and in some systems it is desirable that the feeds be adjusted as desired and independently of each other.

Any oiling device should be as nearly automatic in action as possible and the modern types require but little further attention from the motorist than to keep a proper amount of lubricant in the container. The oil feed to the moving parts should start as soon as the engine begins to turn and the supply should be interrupted when the mechanism stops. The only system which combines all the desirable features is that which includes a mechanical drive from the source of power. Lubricators may be divided into two classes, those which depend upon natural phenomena such as the attraction of gravity or displacement by air pressure, and others which are worked by mechanical means and which deliver the oil in measured quantities by positively driven pumps.

The simplest form of lubricating appliance is that in which oil is carried in a tank or oil cup placed higher than the points to which it is applied and then delivered to the bearing points in drops. A simple form of sight-feed gravity oiler is shown at Fig. 209, A. This device has a glass body so that the amount of oil at the disposal of the motorist may be instantly noted and two sight-feed gauges at the bottom which are connected to the points needing lubricant. The opening through which the oil drips is regulated by an adjustable knurled screw which turns a needle controlling the supply orifice. In

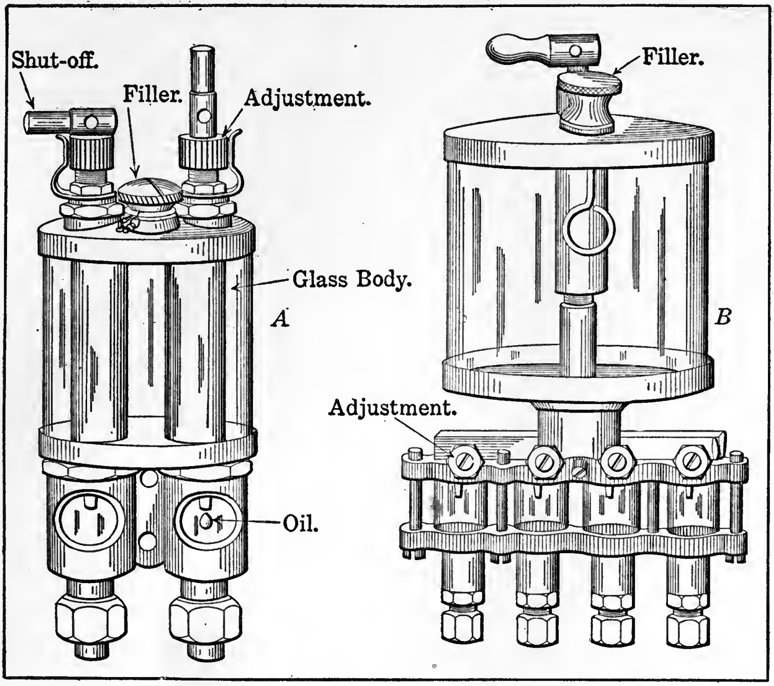


Fig. 209.—Simple Gravity-Feed Oil Cups with Glass Body to Show Height of Lubricant in Container, and Sight Gauges to Give Visible Evidence of Amount of Oil Supplied.

connection with the adjustable feature a simple lever is usually provided by which the needle may be raised from its seat and the oil allowed to flow into the sight-feed glass.

In the device shown at A the shut-off lever, which is horizontally placed, allows the needle to seat against the opening in the bottom of the lubricator and the flow of oil is stopped. When placed vertically, as shown at the right, the needle is raised from its seat and the oil may flow to the part with which the sight-feed glass is coupled. When more than two feeds are desired, the oil from the main container may drip into a manifold fitting which will have any desired number of sight-feed glasses and their individual connections. A gravity oiler having four sight-feed glasses is depicted at Fig. 209, B.

A disadvantage of oilers which depend upon gravity is that great care must be exercised in selecting lubricant which will have the proper viscosity or body to flow under the specific conditions of operation which may obtain at different times. For instance, during warm weather oil will flow readily and heavier bodied lubricants may be used without danger of clogging the supply pipe or the opening in the body of the oiler. When the weather becomes colder the oil may congeal and lighter fluid must be supplied to maintain an uninterrupted feed. Should the oil leads to the bearing become clogged by a particle of foreign matter the oil feed will be interrupted because the weight of the oil is not sufficient to dislodge the particle which hinders its flow. The result is that no oil reaches the bearing point and the part which needs the lubricant will be deprived of oil and cause trouble.

With devices of this form it is necessary to frequently manipulate the adjustments. Every atmospheric change that causes a difference of temperature must be reckoned with, and if the oiler is adjusted during cold weather it will feed too fast when the temperature is higher. If the supply of oil is regulated during warm weather when the oil flows easily, as soon as the lubricant congeals it will not pass through the supply pipes so readily and the opening must be increased in area to compensate for the greater viscosity of the lubricant. The gravity oiler is seldom used in modern automobiles and is only found on cars of early vintage which are still in use in large numbers in some parts of the country. It is utilized to some extent in marine applications where it can be mounted very close to the engine and kept at a uniform temperature by the heat given off from the power plant.

Mechanical Oiling Methods Described.—The oiling systems of the late forms of motor cars depend upon some positive oil pump to maintain circulation of the lubricant or to force it to the bearing point. Two forms of pumps are shown in section at Fig. 210. That at A is a simple plunger pump in which the plunger is operated by means of a cam driven by worm gearing from some suitable point on the power plant. When the pump plunger is drawn out toward the end of the cylinder the suction lifts the inlet check valve, which is a small steel ball, from its seat and the pump cylinder fills with oil. On the down-

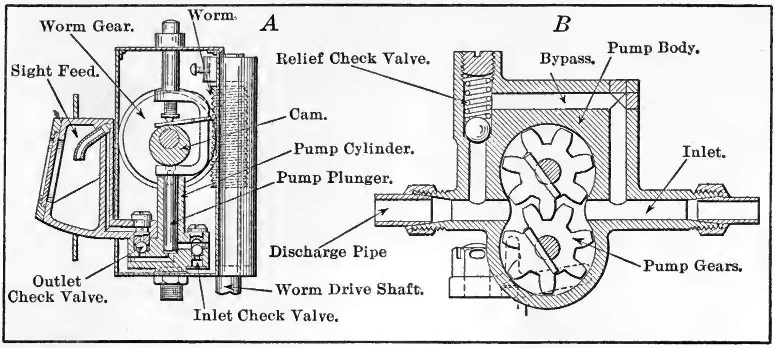


Fig. 210.—Positive Mechanical Methods of Supplying Lubricant. A—Worm Gear Driven Plunger Pump Oiler. B—Gear Pump with High-Pressure Relief Valve.

stroke of the pump plunger the outlet check valve is unseated by the oil pressure and the lubricant is expelled from the pump cylinder to the bearing point in a positive manner and under some degree of pressure. The stroke of the pump plunger may be varied by a suitable adjustment and the quantity of oil directed to the bearing point will depend upon the stroke of the pump plunger. Most forms of the device described use a multiplicity of pumps and individual leads to the different bearing points. The arrangement is such that each bearing is served by its own pump member.

In other systems a single pump of large capacity is used, this supplying oil to a manifold fitting from which it is distributed to the cylinders or to the engine base from which it is picked up and splashed about by fingers on the bottom of the connecting rods. Another form of pump which is used more in maintaining circulation of oil in systems where distribution is by connecting rods than in individual supply systems is shown at B. One of a pair of gears is driven by the engine and turns the other one so that the oil which fills the pump body is entrapped in spaces between the teeth of the gears and forced along through the discharge pipe. The form of pump shown has a ball check valve which seats against an opening which communicates with the discharge pipe. Should there be an obstruction in the piping which will result in excessive pressure the relief valve will unseat and the pressure will be diminished by a quantity of the oil flowing back into the inlet end through the by-pass passage.

Two methods of distributing oil in the interior of internal combustion engines are outlined at Fig. 211. That at A consists in pro-

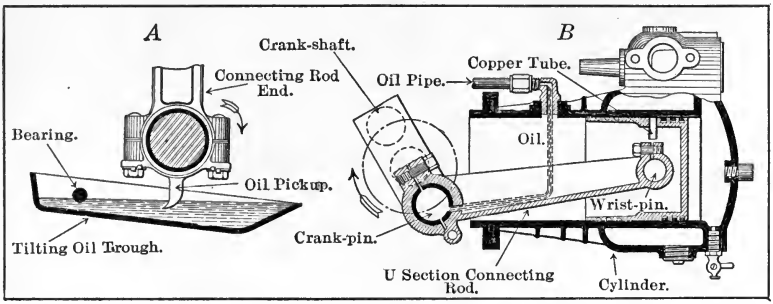


Fig. 211.—How Oil May be Supplied to Interior Mechanism of Internal Combustion Motor. A—Oil Pick-up Finger on Connecting Rod End Dips into Lubricant and Splashes It Over Interior Parts. B—Oil Drops into Channel in Horizontal Connecting Rod and Supplies Bearings and Cylinder.

viding an oil pick-up finger or splasher at the bottom of the connecting rod big end which dips into the lubricant carried in an oil trough directly under the connecting rod. As the crank shaft revolves in the direction of the arrow, a certain amount of lubricant will be picked up from the trough and as the speed increases the rapid movement of the pick-up finger through the oil will splash it around the interior of the motor base. The form of oil trough shown is that used on the Knight engines and it is supported at one end on a bearing rod which is interconnected with the throttle so that as the gas supply is opened up to accelerate the engine, the oil trough is tilted in such a way that the proper quantity of lubricant will be supplied the cylinder.

A simple method which is applicable on engines having horizontally disposed cylinders is outlined at Fig. 211, B. In this the oil is applied to a point about midway in the cylinder and in such a position that it is swept by the piston on its up or downstroke. When in the position shown in the drawing the piston is traveling toward the open end of the cylinder, and until the oil hole is shut off by the wall of the piston the lubricant will drip directly into the bottom of a U section connecting rod. When the rod is at the angle shown the oil will flow to the crank-pin bearings. When the piston reaches a point in the cylinder so that the copper tube carried by it registers with the oil opening the stream of lubricant will pass through the copper tube and onto the wrist pin. The cylinder wall and other points which need oiling are kept covered with a film of oil derived from the spray or mist composed of finely divided particles of oil which is present in the crank case all times the engine is in operation.

Oil Supply by Constant Level Splash System.—The splash system of lubrication that depends on the connecting rod to distribute the lubricant is one of the most successful and simplest forms if some means of maintaining a constant level is provided. If too much oil is supplied the surplus will work past the piston rings and into the combustion chamber, where it will burn and cause carbon deposits. Too much oil will also cause an engine to smoke and an excess of lubricating oil is usually manifested by a bluish-white smoke issuing from the exhaust.

A good method of maintaining a constant level of oil for the successful application of the splash system is shown at Fig. 212. The engine base casting includes a separate chamber which serves as an oil container and which is below the level of oil in the crank case. The lubricant is drawn from the sump or oil container by means of a positive oil pump which discharges directly into the engine case. The level is maintained by an overflow pipe which allows all excess lubricant to flow back into the oil container at the bottom of the cylinder. Before passing into the pump again the oil is strained or filtered by a screen of wire gauze and all foreign matter removed. Owing to the rapid circulation of the oil it may be used over and over again for quite a period of time. The oil is introduced directly into the crank case by a breather pipe and the level is indicated by

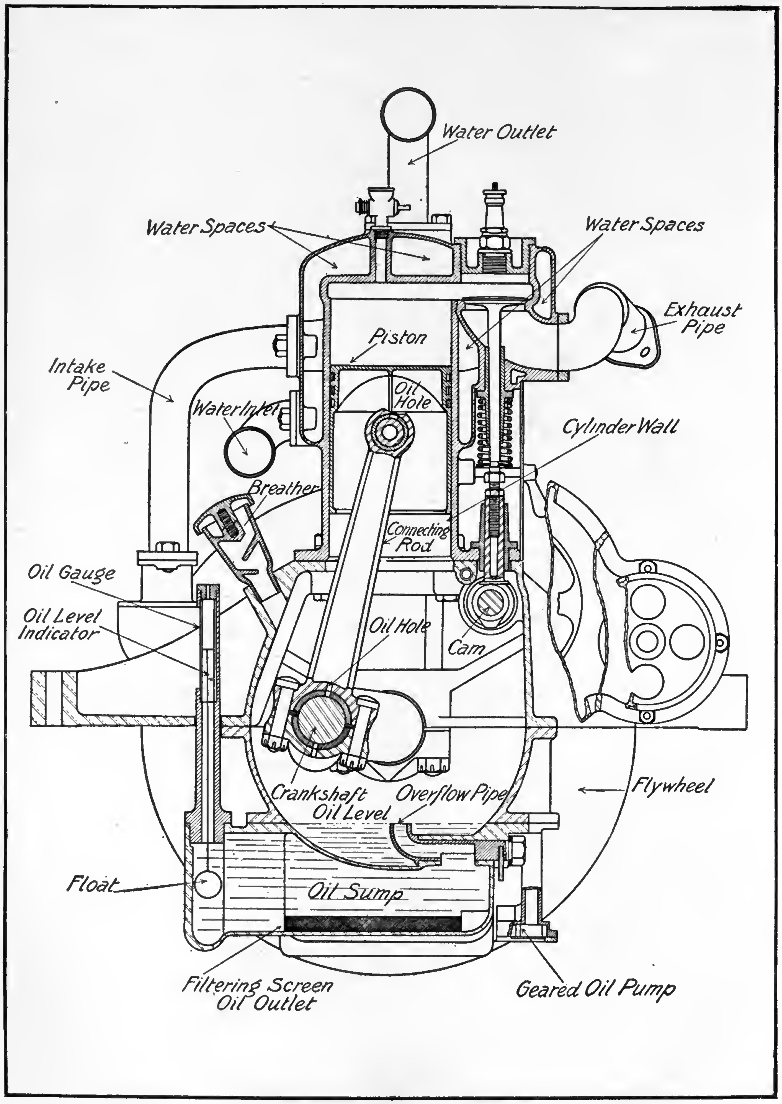


Fig. 212.—Sectional View of Typical Motor Showing Parts Needing Lubrication and Method of Applying Oil by Constant Level Splash System. Note also Water Jacket and Spaces for Water Circulation.

a rod carried by a float which rises when the container is replenished and falls when the available supply diminishes.

The system depicted at Fig. 213 is very similar to that previously described, except that the oil feed from the pump is first directed into an oil manifold pipe from which leads connect to the various main bearings of the engine. The oil dripping from these journals collects in the crank case until it reaches a certain level and then

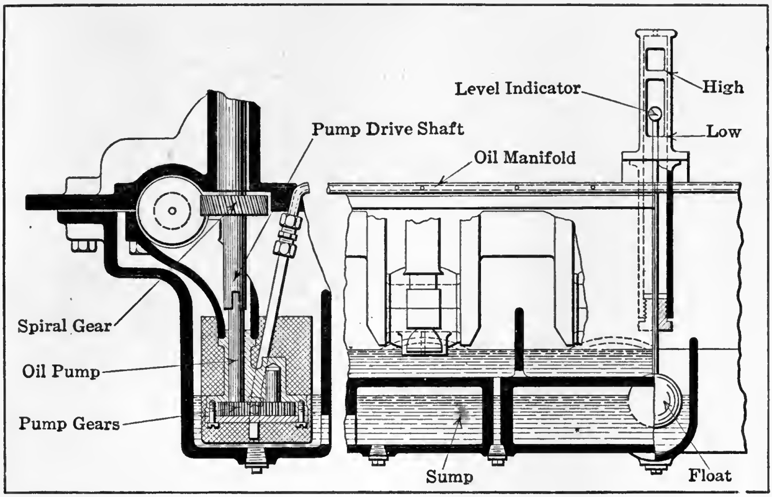


Fig. 213.—Sectional View of Part of Rutenber Engine Depicting Method of Driving Oil Pump and Distribution to Bearing Points.

drains back into the sump or oil container through suitable overflow openings. The ends of the connecting rods are provided with scoops or oil pick-up members which splash the lubricant around the interior of the engine. The amount of oil available is shown by a float controlled indicator, as in the previously described system. The pump is driven from the cam shaft by means of a pair of spiral gears.

It will be noted that with such system the only apparatus required besides the oil tank which is cast integral with the bottom of the crank case is a suitable pump to maintain circulation of oil. This member is always positively driven, either by means of chains and sprockets, shaft and universal coupling, or direct gearing. As the pump is used to circulate oil but little wear will result during the life of the engine because all parts of the pump mechanism are operating in a constant bath of lubricant. The screens or filters are usually in-

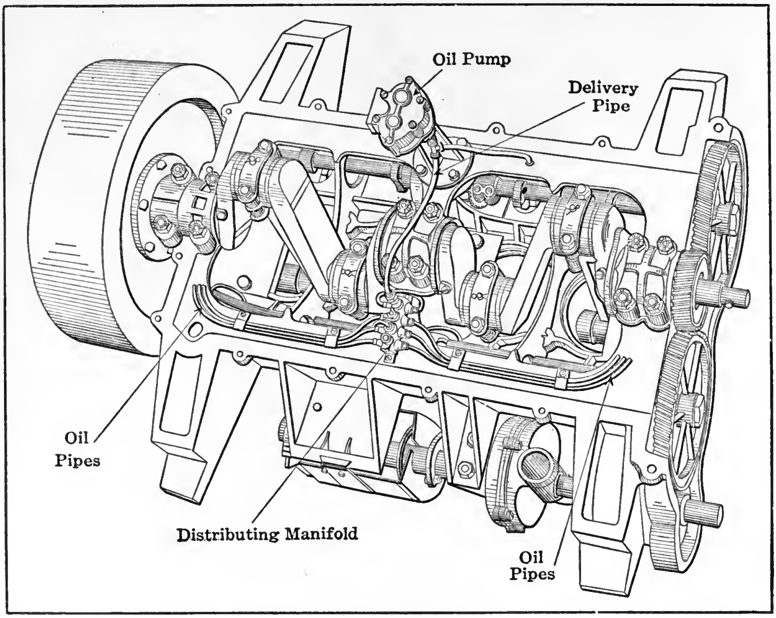


Fig. 214.—Oil Distributing System Employed on Stoddard-Dayton Motor Cars.

stalled at points which will permit them to be easily removed when cleaning is necessary.

The self-contained oiling systems of the constant level type greatly simplify the power plant and insure the economical use of lubricant. The proper level of oil is regulated at the factory by the position of the overflow pipes and it must remain in adjustment because there is no way of altering it on most motors. As the lubricating oil is carried in the bottom of the engine case it is heated up as soon as the engine has been in operation for a few moments, and as the viscosity of the lubricant cannot be altered by varying conditions of temperature or climate the same grade of oil may be employed during the entire year. Other advantages are that the lubricating system is entirely automatic in action, that it will furnish a positive supply of oil at all desired points, and that it cannot be tampered with by the inexpert motorist because no adjustments are provided or needed.

The constant level system may be modified in a number of respects. Sometimes the oil is fed directly to the crank case compartment and the connecting rods depended upon solely to distribute the lubricant. In other systems, the oil delivered by the pump is conveyed to a distributing manifold, as shown at Fig. 214. From this

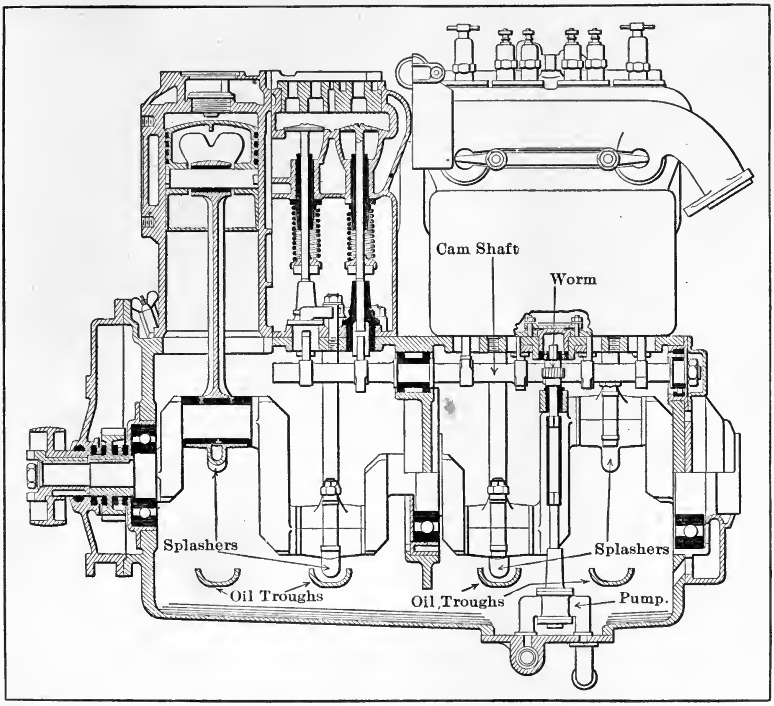


Fig. 215.—Part Sectional View of Motor-Car Engine Showing Oil Distribution by Splashers at the Ends of the Connecting Rods, which Dip into Troughs Disposed Under Them.

manifold member the oil is delivered to important bearing points, such as the main journals, and directly to the cylinder walls by small copper pipes before it is allowed to drain back into the crank case and from this member overflow into the sump or container. In some systems no separate oil container is cast with the crank case, this member being made deeper so that the oil level will be below the point where the connecting rods will pass through it. When this practice is followed small troughs are cast in the engine base into which the scoops on the connecting rod dip, as shown at Fig. 215.

Distributing Lubricant by Pressure.—In some power plants it is considered desirable to supply the oil directly to the parts needing

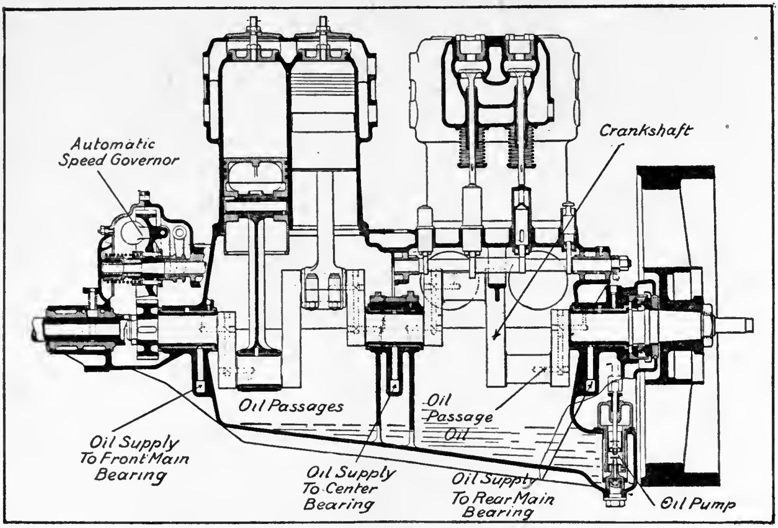


Fig. 216.—Method of Supplying Oil Under Pressure to Main Bearings, from which It is Directed to Connecting Rods by Passages Drilled in Crank Shaft.

it by suitable leads instead of depending solely upon the distributing action of scoops on the connecting rod big ends. A system of this nature is shown at Fig. 216. The oil is carried in the crank case as is common practice, but the normal oil level is below the point where it will be reached by the connecting rod. It is drawn from the crank case by a plunger pump which directs it to a manifold leading directly to conductors which supply the main journals. After the oil has been used on these points it drains back into the bottom of the crank case. An excess is provided which is supplied to the connecting rod ends by passages drilled into the webs of the crank shaft and part way into the crank pins as shown by the dotted lines. The oil which is present at the connecting rod crank pins is thrown off by centrifugal force and lubricates the cylinder walls and other internal parts. Small cups are cast at the upper end of the connecting rods to collect oil, and suitable passages allow the lubricant to flow between the wrist pin and wrist-pin bushing.

Individual pump oilers are not so widely used at the present time as they have been in the past, but a number of designers still contend that these devices are superior to the simpler splash systems because only clean oil is delivered to the bearing points and in measured quantities. It is contended that with splash systems the oil soon becomes impregnated with minute carbon particles and that it is not as suitable for lubricating purposes as the clean lubricant supplied

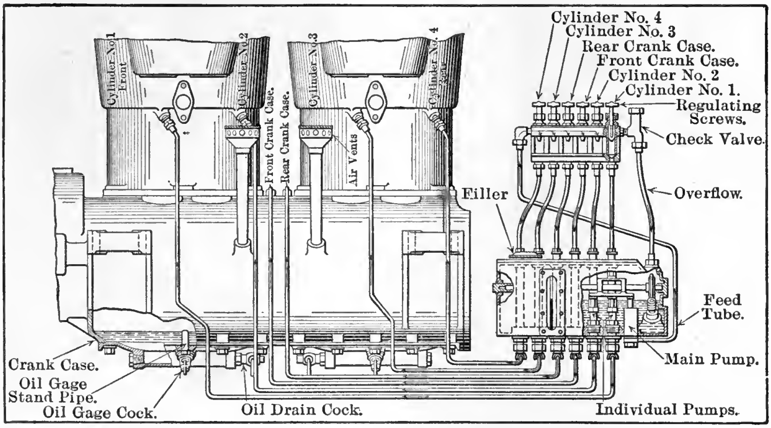


Fig. 217.—Showing Application of Mechanical Oiler having Individual Pumps and Leads to Bearing Points in Connection with Sight-Feed Gauge on Dash.

from the mechanical oiler. In most systems where a mechanical oiler is employed the splash system is depended upon to a certain extent as well, so that it is not readily apparent how the disadvantage cited can be applied in favor of the individual pump method of supply.

A typical system using a mechanical oiler is outlined at Fig. 217. In this one main pump supplies a manifold fitting carried on the dashboard from which the oil drips into sight gauges through needle-valve regulated orifices. A series of smaller individual pumps draw the oil from the sight-feed manifold and force it through pipes which communicate with the individual cylinders and with the front and

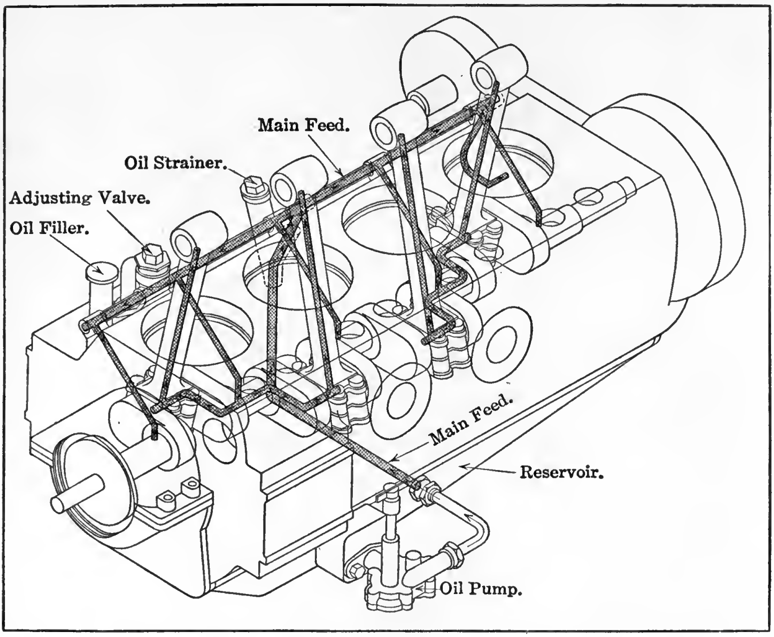


Fig. 218.—Oil-Supply System Utilized on Knox Automobile Power Plants has Many Good Features.

rear crank case compartments respectively. Regulating screws are provided so that the amount of oil supplied the different points may be regulated at will. A relief check valve is installed to take care of excess lubricant and to allow any oil that does not pass back into the individual pumps to overflow into the main container.

Two typical systems in which the oil is first supplied to the main bearings and from thence to the connecting rods by means of passages in the crank shaft are shown at Figs. 218 and 219. The former is used on Knox motor cars and is shown graphically in a phantom view of the crank case in which the oil passages are made specially prominent. The oil is taken from a reservoir at the bottom of the engine base by the usual form of gear oil pump and is supplied to a main feed manifold which extends the length of the crank case. Individual conductors lead to the five main bearings, which in turn supply the crank pins through passages drilled through the crank-shaft web. In this power plant the connecting rods are hollow section bronze castings and the passage through the center of the connecting rod serves to convey the lubricant from the crank pins to the wrist pins. The cylinder walls are oiled by the spray of lubricant thrown off the revolving crank shaft by centrifugal force.

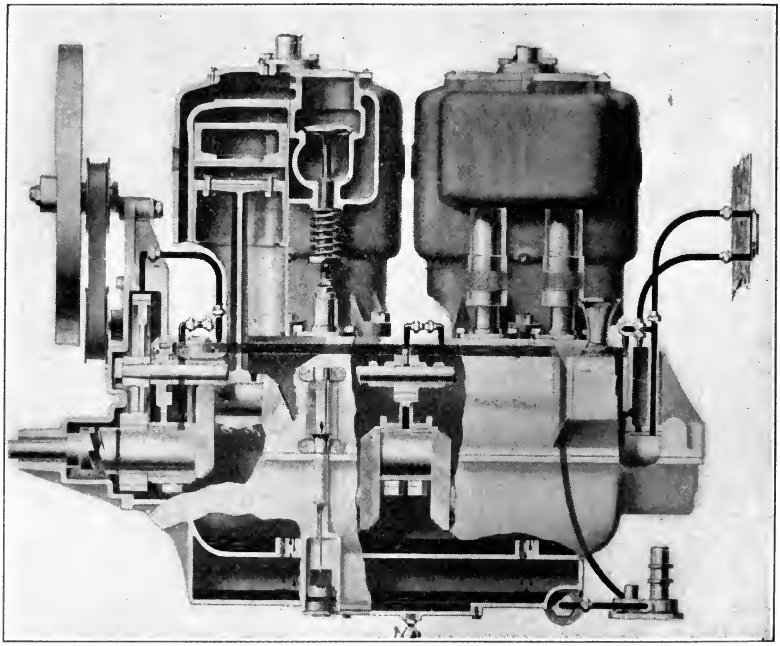


Fig. 219.—Constant-Level Positive-Supply System Used in Columbia "Mark 85" Motor.

The system outlined at Fig. 219 is similar in principle to that previously described. In this view the engine is shown in part section and as the oil delivery pipes and conduits are shown by heavy black lines it will not be difficult to follow the oil from the sump at the bottom of the crank case through the oil pump and the leads to the main bearing and timing gear case. A sight gauge is shunted into the main circuit and is placed on the dash so the motorist may ascertain at any time if the components of the oil system are functioning properly. A float controlled level indicator is carried at the side of the crank case so that one may tell at a glance if there is an adequate supply of oil in the container.

Why Cooling Systems Are Necessary.—The reader should understand from preceding chapters that the power of an internal combustion motor is obtained by the rapid combustion and consequent expansion of some inflammable gas. The operation in brief is that when air or any other gas or vapor is heated, it will expand and that if this gas is confined in a space which will not permit expansion, pressure will be exerted against all sides of the containing chamber. The more a gas is heated, the more pressure it will exert upon the walls of the combustion chamber it confines. Pressure in a gas may be created by increasing its temperature and inversely heat may be created by pressure. When a gas is compressed its total volume is reduced and the temperature is augmented.

The efficiency of any form of heat engine is determined by the power obtained from a certain fuel consumption. A definite amount of energy will be liberated in the form of heat when a pound of any fuel is burned. The efficiency of any heat engine is proportional to the power developed from a definite quantity of fuel with the least loss of thermal units. If the greater proportion of the heat units derived by burning the explosive mixture could be utilized in doing useful work the efficiency of the gasoline engine would be greater than that of any other form of energizing power. There is a great loss of heat from various causes, among which can be cited the reduction of pressure through cooling the motor and the loss of heat through the exhaust valves when the burned gases are expelled from the cylinder.

The loss through the water jacket of the average automobile power plant is over 50% of the total fuel efficiency. This means that more than half of the heat units available for power are absorbed and dissipated by the cooling water. Another 16% is lost through the exhaust valve, and but $33\frac{1}{3}$% of the heat units do useful work. The great loss of heat through the cooling systems cannot be avoided, as some method must be provided to keep the temperature of the engine within proper bounds. It is apparent that the rapid combustion and continued series of explosions would soon heat the metal portions of the engine to a red heat if some means were not taken to conduct much of this heat away. The high temperature of the parts would burn the lubricating oil, even that of the best quality, and the piston and rings would expand to such a degree, especially when deprived of oil, that they would seize in the cylinder. This would score the walls, and the friction which ensued would tend to bind the parts so tightly that the piston would stick, bearings would be burned out, the valves would warp, and the engine would soon become inoperative.

The best temperature to secure efficient operation is one on which considerable difference of opinion exists among engineers. The fact that the efficiency of an engine is dependent upon the ratio of heat converted into useful work compared to that generated by the explosion of the gas is an accepted fact. It is very important that the engine should not get too hot, and at the other hand it is equally vital that the cylinder be not robbed of too much heat. The object of cylinder cooling is to keep the temperature of the cylinder below the danger point but at the same time to have it as high as possible to secure maximum power from the gas burned.

Cooling Systems Generally Applied.—There are two general systems of engine cooling in common use, that in which water is heated by the absorption of heat from the engine and then cooled by air, and the other method in which the air is directed onto the cylinder and absorbs the heat directly instead of through the medium of water. When the liquid is employed in cooling it is circulated through jackets which surround the cylinder casting and the water may be kept in motion by two methods. The one generally favored is to use a positive circulating pump of some form which is driven by the engine to keep the water in motion. The other system is to utilize a natural principle that heated water is lighter than cold liquid and that it will tend to rise to the top of the cylinder when it becomes heated to the proper temperature and cooled water takes its place at the bottom of the water jacket.

Air-cooling methods may be by radiation or convection. In the former case the effective outer surface of the cylinder is increased by the addition of flanges or spines cast thereon, and the air is depended on to rise from the cylinder as heated and be replaced by cooler air. When a positive air draught is directed against the cylinders by means of a fan, cooling is by convection and radiation both. Sometimes the air draught may be directed against the cylinder walls by some form of jacket which confines it to the heated portions of the cylinder.

Cooling by Positive Water Circulation.—A typical water-cooling system in which a pump is depended upon to promote circulation of the cooling liquid is shown at Fig. 220, and the components of such a group are shown separately so the construction may be more easily understood at Fig. 221. The radiator is carried at the front end of

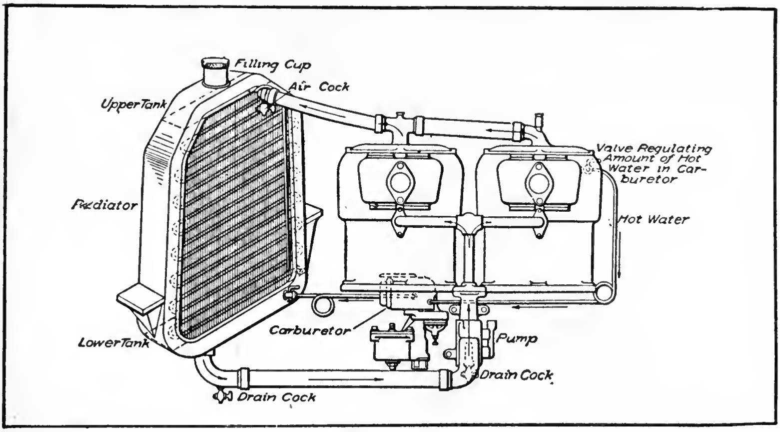


Fig. 220.—Components of Typical Motor-Car-Cooling Group Utilizing Pump to Maintain Circulation of Liquid. System Shown Used on Peerless Cars with Success.

the car in most cases and serves as a combined water tank and cooler. It is composed of an upper and lower portion joined together by a series of pipes which may be round and provided with a series of fins to radiate the heat, or which may be flat in order to have the water pass through in thin sheets and cool it more easily. Cellular or honeycomb coolers are composed of a large number of bent tubes which will expose a large area of surface to the cooling influence of the air draught forced through the radiator either by the forward movement of the vehicle or by some type of fan. The cellular and flat tube types have almost entirely displaced the flange tube radiators which were formerly popular because they cool the water more effectively, and may be made lighter than the tubular radiator could be for engines of the same capacity.

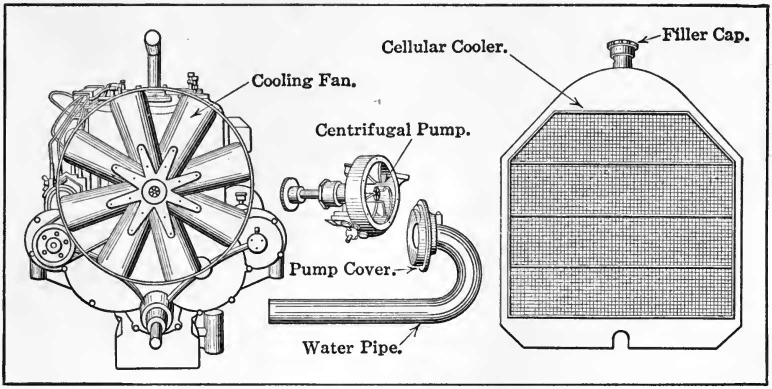


Fig. 221.—Elements of Typical Cooling Group, Defining Construction of Centrifugal Pump, Cooling Fan and Cellular Cooler.

The water is drawn from the lower header of the radiator by the pump and is forced through a manifold to the lower portion of the water jackets of the cylinder. It becomes heated as it passes around the cylinder walls and combustion chambers and the hot water passes out of the top of the water jacket to the upper portion of the radiator. Here it is divided in thin streams and directed against comparatively cool metal which abstracts the heat from the water. As it becomes cooler it falls to the bottom of the radiator because its weight increases as the temperature becomes lower. By the time it reaches the lower tank of the radiator it has been cooled sufficiently so that it may be again passed around the cylinders of the motor. In some cooling systems, especially those employing cellular type coolers, it is necessary to use a cooling fan to draw currents of air through the interstices of the cooler.

The pumps used differ in design. The form shown at Fig. 221 and at Fig. 222, A, is known as the "centrifugal type" because a rotary impeller of paddle-wheel form throws water which it receives at a central point toward the outside and thus causes it to maintain a definite rate of circulation. The pump may be a separate appliance,

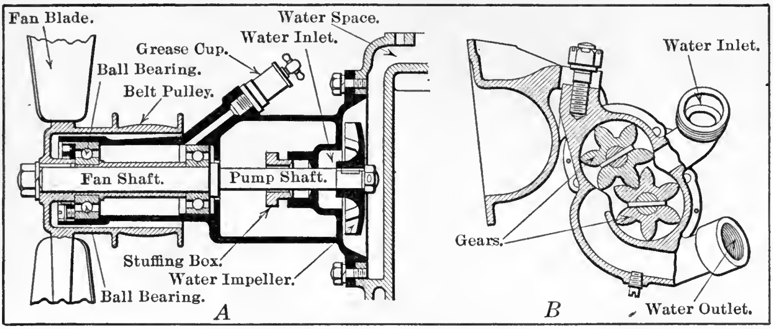


Fig. 222.—Two Forms of Water-Circulating Pumps Representing Current Practice. A—Cooling Fan and Water Pump Driven from Common Source by Single Belt; Pump Impeller Placed Directly in Water Jacket. B—Gear Circulating Pump.

as shown at Figs. 220 and 221, or it may be incorporated in part of the water jacket, as depicted at Fig. 222, A. The centrifugal pump is not as positive as the gear form shown at Fig. 222, B, and some manufacturers prefer the latter because of the positive pumping features. They are very simple in form, consisting of a suitable cast body in which a pair of spur pinions having large teeth are carried. One of these gears is driven by suitable means and as it turns the other member they maintain a flow of water through the central portion of the pump. The pump should always be installed in series with the water pipe which conveys the cool liquid from the lower compartment of the radiator to the coolest portion of the water jacket.

Water Circulation by Natural System.—Some engineers contend that the rapid water circulation obtained by using a pump may cool the cylinders too much, and that the temperature of the engine may be reduced so much that the efficiency will be lessened. For this reason there is a growing tendency to use the natural method of water circulation as the cooling liquid is supplied to the cylinder jackets just below the boiling point, and the water issues from the jacket at the top of the cylinder after it has absorbed sufficient heat to raise it just about to the boiling point.

The cooling system depicted at Fig. 223 is one that has demonstrated its worth conclusively in practice and is somewhat simpler than the forms in which a pump is used to maintain circulation. With this method, the fact that water becomes lighter as its temperature becomes higher is taken advantage of in securing circulation around the cylinders. The top of the water jacket of the individually cast cylinders is attached to the center of the radiator, while

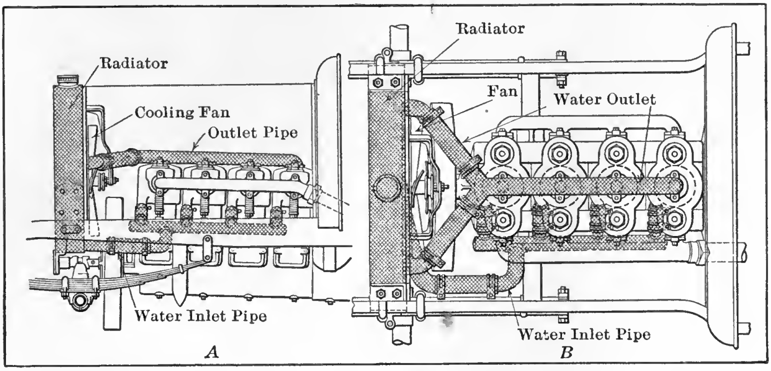


Fig. 223.—Water-Cooling Group Used on Maxwell Automobiles in which Water Circulation is Maintained by Natural Means. A—Side View of Power Plant Showing Application of Piping. B—Plan View Outlining Disposition of Parts.

the pipe leading from the bottom of that member is connected to a manifold which supplies cool water to the bottom of the cylinder jackets. With such a system it is imperative that the radiator be carried at such a height that the cool water will flow to the water spaces around the cylinder by gravity.

As the water becomes heated by contact with the hot cylinder and combustion-chamber walls it rises to the top of the water jackets, flows to the cooler, where enough of the heat is absorbed to cause it to become sensibly greater in weight. As the water becomes cooler, it falls to the bottom of the radiator and it is again supplied to the water jacket. The circulation is entirely automatic and continues as long as there is a difference in temperature between the liquid in the water spaces of the engine and that in the cooler. The circulation becomes brisker as the engine becomes hotter and thus the temperature of the cylinders is kept more nearly to a fixed point. With the thermosyphon system the cooling liquid is nearly always at its boiling point, whereas if the circulation is maintained by a pump the engine will become cooler at high speed and will heat up more at low speed.

There are two methods of applying the thermosyphon system in a practical manner, the most common being that outlined at Fig. 223. Here the radiator is carried at the front end of the car and a fan

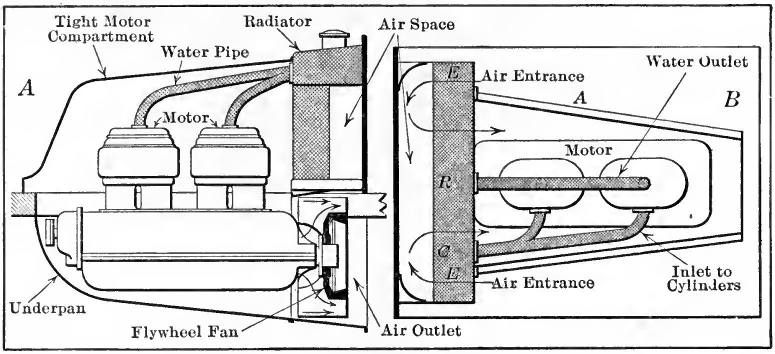


Fig. 224.—Renault Thermosyphon System, in which Radiator is Placed in Back of Engine Instead of in Front, as is Conventional Practice. A—Showing Method of Utilizing Fan Fly Wheel to Insure Air Circulation Through Radiator. B—Plan View Depicting Flow of Air Currents Through Cooler.

driven from the crank shaft by belt connection is used to draw the air through the radiator. The other system, which is illustrated at Fig. 224, is one that was introduced on the Renault automobile In this the radiator is mounted just forward of the dashboard instead of at the front of the frame. The air draught through the radiator is produced by the suction effect of a fan member which is incorporated with the fly wheel.

When a radiator is mounted at the front end of a frame, it is one of the most vulnerable portions of the motor-car mechanism, and as they are delicately constructed they may be easily damaged in collision. When installed as shown at Fig. 224, they are protected by the heavier construction of the cylinders and other portions of the motor and are not liable to be damaged. Then again, as the fan is incorporated with the fly wheel and driven directly by the crank shaft of the motor, there is no possibility of failure of this member, such as might be possible when it is driven by a belt connection from the front end of the engine.

With the thermosyphon or natural system of cooling more water must be carried than with the pump maintained circulation methods.

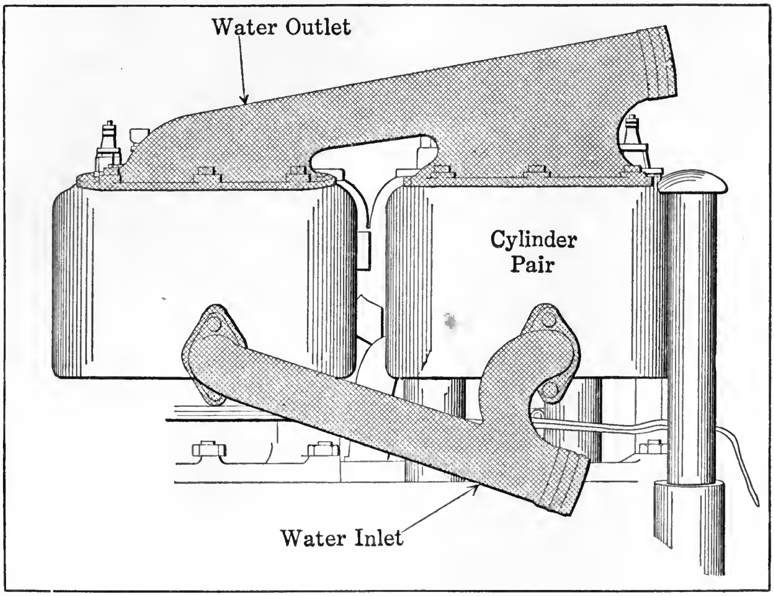


Fig. 225.—Showing Large Water Manifolds Designed to Secure Positive Circulation by Thermosyphon or Natural Methods.

The water spaces around the cylinders should be larger, the inlet and discharge water manifolds should have greater capacity, and be free from sharp corners which might impede the flow. The radiator must also carry more water than the form used in connection with the pump because of the brisker pump circulation which maintains the engine temperature to a lower point. The large piping which experience has shown necessary is clearly shown in views previously described and in Fig. 225.

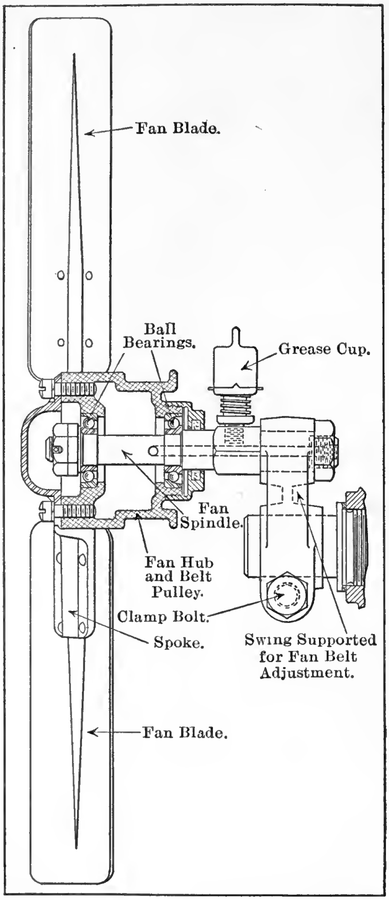


Fig. 226.—Typical Ball-Bearing, Hub-Cooling Fan Designed to Create Air Draught Through Radiator and Around Cylinders of Motor-Car Power Plant.

The form of fan which is generally placed behind the radiator with either system of water cooling and which is often used in the simple air-cooling systems as well, is shown in part section at Fig. 226. The hub is usually a cast-aluminum member which has a series of projecting spokes to which the fan blades are riveted. The blades are inclined at the proper angle to draw air through the radiator and force it to the rear of the motor compartment. As a fan requires but little power, they are usually driven by small leather belts and as they operate at speeds two or three hundred per cent greater than that of the motor-crank shaft they are mounted on ball bearings in order that they may turn with as little friction as possible. The fan spindle is usually supported by some form of movable bracket which can be adjusted so that the fan belt may be maintained at a constant degree of tension.

Direct Air-Cooling Methods.—The earliest known method of cooling the cylinder of gas engines was by means of a current of air passed through a jacket which confined it close to the cylinder walls and was used by Daimler on his first gas engine. The gasoline engine of that time was not as efficient as the later form, and other conditions which materialized made it desirable to cool the engine by water. Even as gasoline engines became more and more perfected there has always existed a prejudice against air cooling, though many forms of engines have been used, both in stationary and automobile applications where the air-cooling method has proven to be very practical.

The simplest system of air cooling is that in which the cylinders are provided with a series of flanges which increase the effective radiating surface of the cylinder and directing an air current from a fan against the flanges to absorb the heat. This increase in the avail-

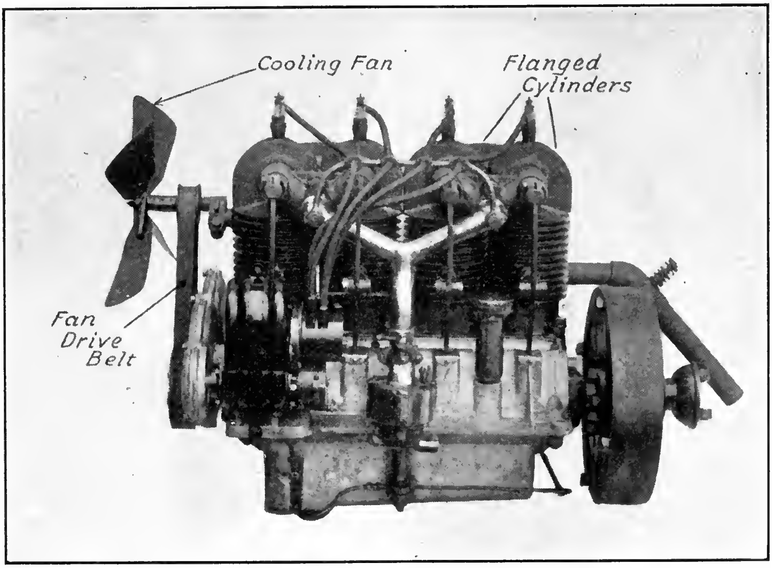


Fig. 227.—Air-Cooling System Employed on Cameron Motors Depends Upon Air Draught from Fan to Circulate Around Flanges on Cylinders and Absorb Excess Heat.

able radiating surface of an air-cooled cylinder is necessary because air does not absorb heat as readily as water and therefore more surface must be provided that the excess heat be absorbed sufficiently fast to prevent distortion of the cylinders. Air-cooling systems are based on a law formulated by Newton, which is: "The rate for cooling for a body in a uniform current of air is directly proportional to the speed of the air current and the amount of radiating surface exposed to the cooling effect." A simple four-cylinder power plant in which cooling is obtained by air blast against the flanges of the cylinders is depicted at Fig. 227, and views of a cylinder and detachable head construction also adapted to be cooled by air are shown at Fig. 228.

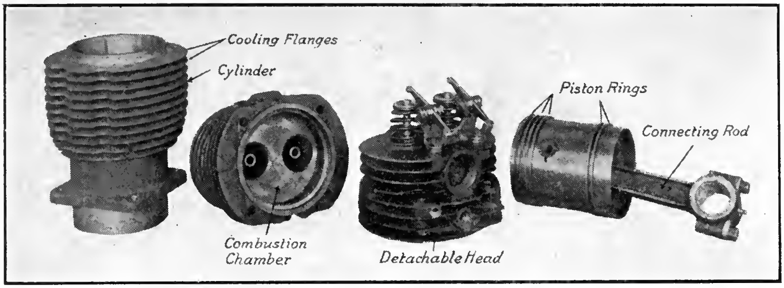


Fig. 228.—Parts of Air-Cooled Cylinder Showing Method of Seating Valves Directly in Detachable Cylinder Head, and Large Flanges on Both Cylinder and Head Member to Largely Increase Effective Radiating Surface.

There are certain considerations which must be taken into account in designing an air-cooled engine, which are often overlooked in those forms cooled by water. Large valves must be provided to insure rapid expulsion of the flaming exhaust gas and also to admit promptly the fresh cool mixture from the carburetor. The valves of air-cooled engines are usually placed in the cylinder head, as shown at Figs. 227 and 228, in order to eliminate any pockets or sharp passages which would impede the flow of gas or retain some of the products of combustion and their heat. When high power is desired multiple-cylinder engines should be used, as there is a certain limit to the size of a successful air-cooled cylinder. Much better results are secured from those having small cubical contents because the heat from small quantities of gas will be more quickly carried off than from greater amounts. All successful engines of the automobile type which have been air cooled have been of the multiple-cylinder type and the use of single cylinders is confined to power plants of less than five horse power such as used in motorcycle construction.

An air-cooled engine must be placed in a chassis in such a way that there will be a positive circulation of air around it all the time that it is in operation. This air current may be produced by a fan at the front end of the motor, by natural draught when a car is in motion, or by a suction or blower fan in the fly wheel. Greater care is required in lubrication of the air-cooled cylinders and only the best quality of oil should be used to insure satisfactory oiling.

The combustion chambers must be proportioned so that distribution of metal is as uniform as possible in order to prevent uneven expansion during increase in temperature and uneven contraction when the cylinder is cooled. It is essential that the inside walls of the combustion chamber be as smooth as possible because any sharp angle or projection may absorb sufficient heat to remain incandescent and cause trouble by igniting the mixture before the proper time. The best grades of cast iron should be used in the cylinder and piston and the machine work must be done very accurately so the piston will operate with minimum friction in the cylinder.

Utility of Auxiliary Exhaust Valves.—As an example of the care taken in disposing of the exhaust gases in order to obtain practical air cooling the illustration at Fig. 229 is presented. This is a section through the bottom of one of the Franklin power plants and shows the auxiliary exhaust valve which is furnished as an adjunct to the regular member in the cylinder head. The auxiliary exhaust valve opens just as soon as the full force of the explosion has been spent and the greater portion, or 70%, of the flaming gases is discharged through the port in the bottom of the cylinder. But 30% of the exhaust gases remain to be discharged through the regular exhaust member in the cylinder head and this will not heat the walls of the cylinder nearly as much as the larger quantity of hot gas would. That the auxiliary exhaust valve is of considerable value is conceded by many engineers unless exceptional care is taken in the method of cooling employed. The earlier Franklin engine, which used the auxiliary exhaust valves, was cooled by an air blast from a fan at the front end which was directed against flanges applied to the cylinders, but on later models the auxiliary valve has been dispensed with because the more positive system of cooling provided makes its use unnecessary.

One of the important considerations in connection with air cooling is that the air blast be confined as close to the cylinders as possible and a more energetic flow of air is needed than with water-cooling

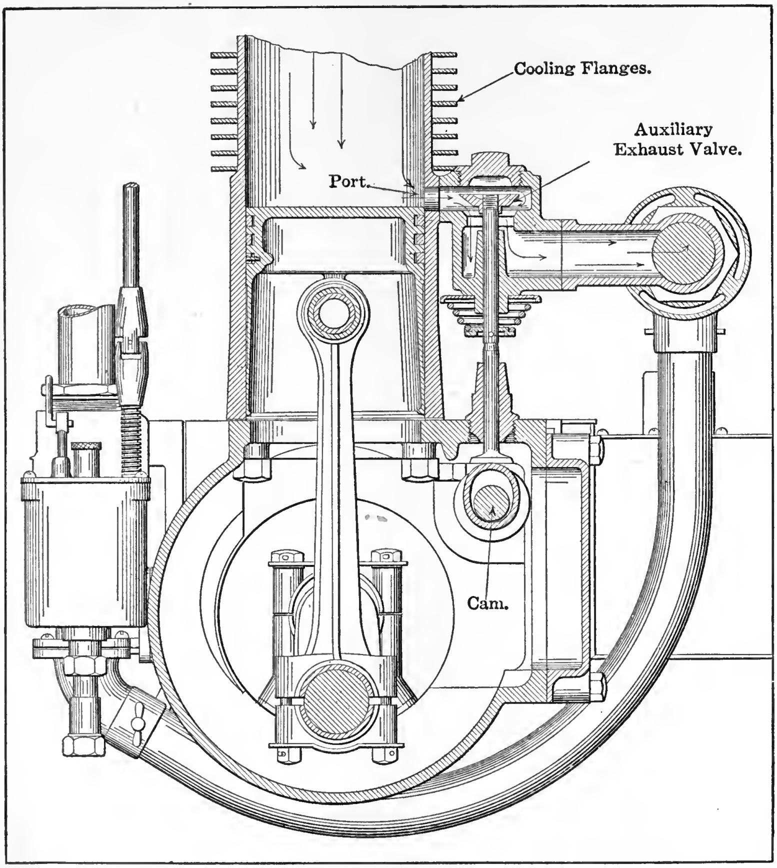


Fig. 229.—Depicting Section Through Power Section of One Type of Franklin Engine, Showing Application of Auxiliary Exhaust Valve to Relieve Cylinder of Flaming Gases at End of Power Stroke.

systems. The form of fan shown at Fig. 226 and at Fig. 230, A, is considered entirely adequate for water-cooled engines, but engineers who favor air cooling at the present time use blower forms such as shown at Fig. 230, B, which will furnish larger quantities of air than the simple fan would and which also direct it to the cylinders in a positive manner by enclosing them in air jackets which are attached to a manifold member to which the discharge opening of the blower is coupled.

The discussion of air cooling so far has considered only the adaptability to the four-stroke motor and many believe that it is not possible

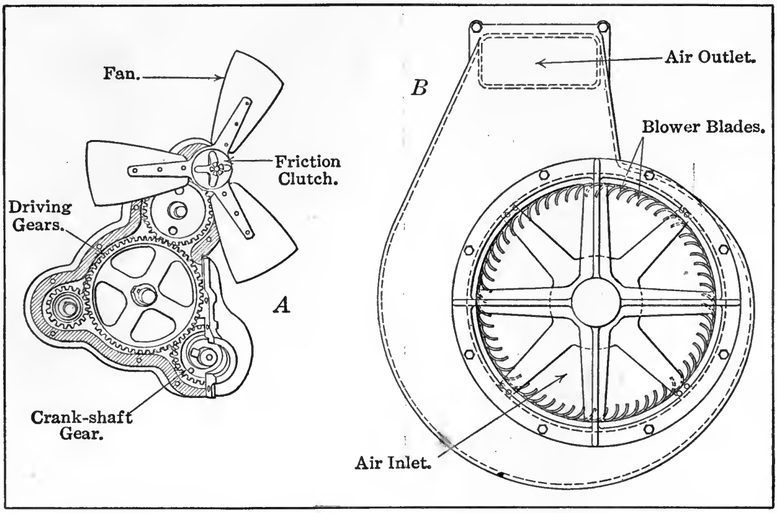


Fig. 230.—Two Forms of Positive Air Fans Used in Automobile-Cooling Systems. A—Gear-Driven, Three-Blade Fan Utilized to Draw Air Through Winton Radiator. B—Blower Member Used on Kelly Air-Jacketed Cylinder Motor.

to cool two-cycle engines by this method because the great heat generated in engines of this type is thought to make the use of water cooling imperative. As the two-cycle motor has an explosion in each cylinder, every revolution of the crank shaft, and has no strokes devoted exclusively to scavenging, it is true the cylinder walls will heat up more. Several forms of two-cycle engines have been evolved, however, in which positive cooling has been obtained by providing the cylinders with cooling ribs. One of these, which is used in the Chase light truck, is depicted in section at Fig. 231. It will be noted that the exhaust ports are large and that the transfer port for the passage of the gas from the crank case to the cylinder is proportioned so that it will have a minimum resistance to the gas flow.

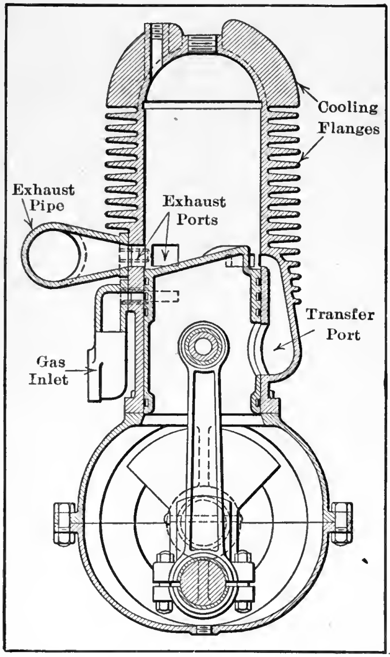


Fig. 231.—Sectional View of Chase Two-Cycle Engine, a Two-Stroke Form Successfully Cooled by Air Flanges Cast Integral with Cylinder.

Two engines of modern development which utilize positive air-cooling methods are shown at Figs. 232 and 233. The system of cooling is practically the same in both instances, except in the methods employed of creating the air blast. In the Franklin system the cylinders are provided with vertical ribs, or flanges, and are encased by jackets which form part of a sheet-metal casing that covers the entire lower portion of the power plant. The fly wheel is provided with a series of curved blower blades and as it turns it creates a partial vacuum in the compartment formed by the motor-base casing and the air-tight underpan. The strong suction created draws air in from the front end of the bonnet and down through the cylinder jackets. The air currents pass over the flanges at high velocity and as there is a large amount of exposed surface the excess heat is promptly disposed of and absorbed by the air passing around the cylinders which is ejected from the motor-base compartment by the action of the blower fly wheel. As the fan is part of the balance member and is driven direct from the engine crank shaft there can be no failure of the driving means and a positive air draught must be induced around the cylinders as soon as the motor is started. The velocity of the air currents increase directly as the motor speed augments, and positive cooling is obtained under all conditions.

In the Frayer-Miller engine which is used in the Kelly trucks, the method of cooling is different in detail but practically the same in principle as that previously described. An air blower is mounted at the front end of the motor and the strong current of air it produces is conveyed to an air pipe at the top of the cylinders, to which the jackets surrounding them are attached. The cylinder heads are provided with a series of vertical flanges, but the cylinder-wall area is

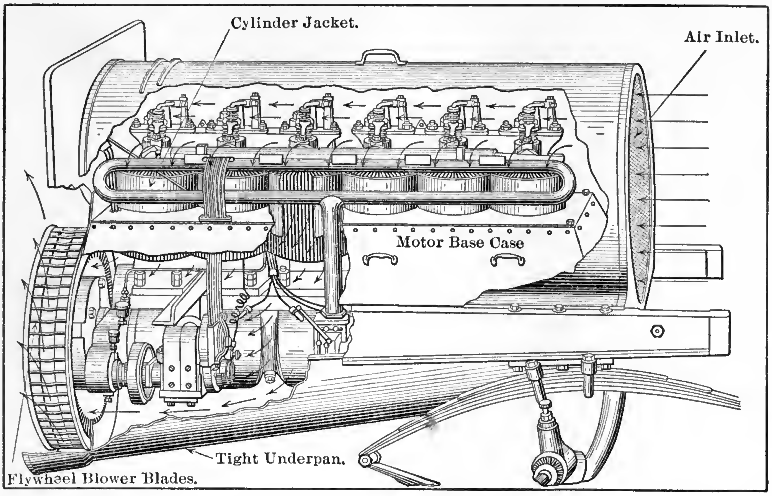


Fig. 232.—Positive Cooling Method Used on Franklin Automobiles in which Air Currents are Drawn Through Cylinder Jackets by Fly-wheel Fan Suction.

increased by using a large number of spines which are cast integral with the cylinder. The air blower forces a blast of air into the air pipe above the cylinders at considerable pressure, and the only way it can escape is by passing around the heated portion of the cylinder before it is discharged through the bottom of the air jacket. As the blower speed increases with engine speed the value of the air current becomes greater when an augmented cooling effect is desired.

Among the advantages stated for air cooling the greatest is the elimination of cooling water, which is a factor of some moment. In the temperate zone, where the majority of automobiles are used, the weather conditions change in a very few months from the warm summer to the extreme cold winter, and when water-cooled systems are employed it is necessary to add some chemical substance to the water to prevent it from freezing. The substances commonly employed are glycerine, wood alcohol, or a saturated solution of calcium chloride. Alcohol has the disadvantage in that it vaporizes readily and must be often renewed. Glycerine affects the rubber hose, while the calcium chloride solution crystallizes and deposits salt in the radiator and water pipes.

Obviously the elimination of water and the use of air cooling will provide a system that will be fully as effective during the extreme

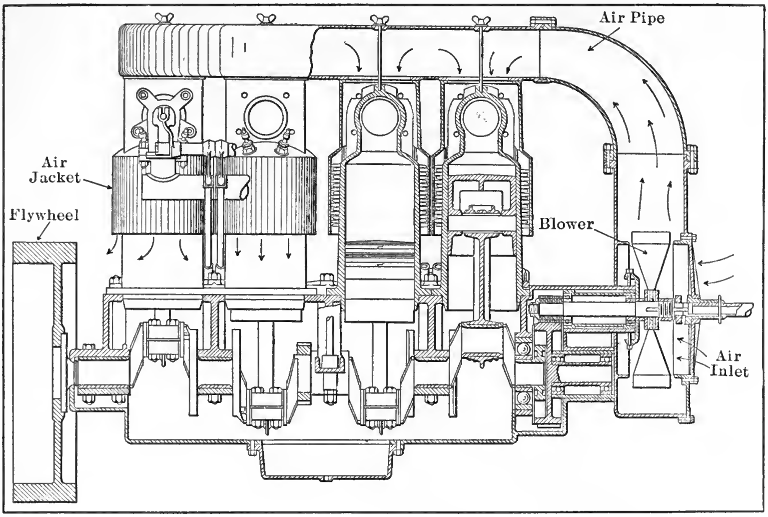


Fig. 233.—Air-Jacketed Frayer-Miller Engine Used in Kelly Trucks Cooled by Air Currents Directed Over Cylinders by Positive Air-Blower System.

cold weather as it is during the more favorable summer season. It would seem that air-cooling methods could be applied to advantage in commercial vehicle power plants which must be capable of efficient service under widely varying conditions. One of the disadvantages of an air-cooling method as stated by those who do not favor this system is that engines cooled by air cannot be operated for extended periods under overloads or at very high speed without heating up to such a point that premature ignition of the charge may result. The water-cooling systems, at the other hand, maintain the temperature of the engine more nearly constant than is possible with an air-cooled motor, and an engine cooled by water can be operated under conditions of inferior lubrication or poor mixture adjustment that would seriously interfere with proper and efficient cooling by air.

Air-cooled motors, as a rule, use less fuel than water-cooled engines because the higher temperature of the cylinder does not permit of a full charge of gas being inspired on the intake stroke. As special care is needed in driving an air-cooled car to obtain satisfactory results and because of the greater difficulty which obtains in providing proper lubrication and fuel mixtures which will not produce undue heating, the air-cooled system has but few adherents at the present time and practically all automobiles, with but very few exceptions, are provided with water-cooled power plants.

CHAPTER VIII

Utility of Clutches and Gearsets Defined—Why These Vital Components of the Transmission System Are Needed on Gasoline Motor-driven Vehicles—Conventional Forms of Cone Clutch and their Practical Application—Characteristics of Three- and Five-plate and Multiple-disk Clutches—Function of Gearset—Types of Speed Changing Mechanism—The Friction Transmission—Planetary and Individual Clutch Types—Progressive and Selective Sliding Gearsets—Typical Speed Changing Mechanisms Outlined.

One of the important functions making for efficient operation of the gasoline motor car is the method of power transmission employed. While power plant efficiency is an important factor and one that should be conserved to the utmost, it is well to remember that the actual power of the car is not the rated power of the engine but the amount of energy exerted at the point of contact between the traction members and the ground. A 60 H. P. car in which there is a 30% loss in power transmission is not as efficient as a vehicle of but 45 H. P. which delivers the power to the rear wheels with but 10% loss. Under the conditions stated the rear wheels of the lower-powered car would actually receive more useful effort than the driving members of the high-powered vehicle, and the energy is supplied with less stress on the various parts and with a lower fuel consumption.

The attention of mechanical engineers had been directed to the efficient transmission of power long before the motor car was commercially practical. As a result many ingenious systems which had been applied in standard mechanical work and for driving the machine tools of manufacturing establishments have been readapted for use in motor-car propulsion. One who has studied the subject can easily trace the evolution from the crude forms of a decade ago to the perfected types used in modern automobiles. The problem of power transmission in motor cars was one that was not easily solved,

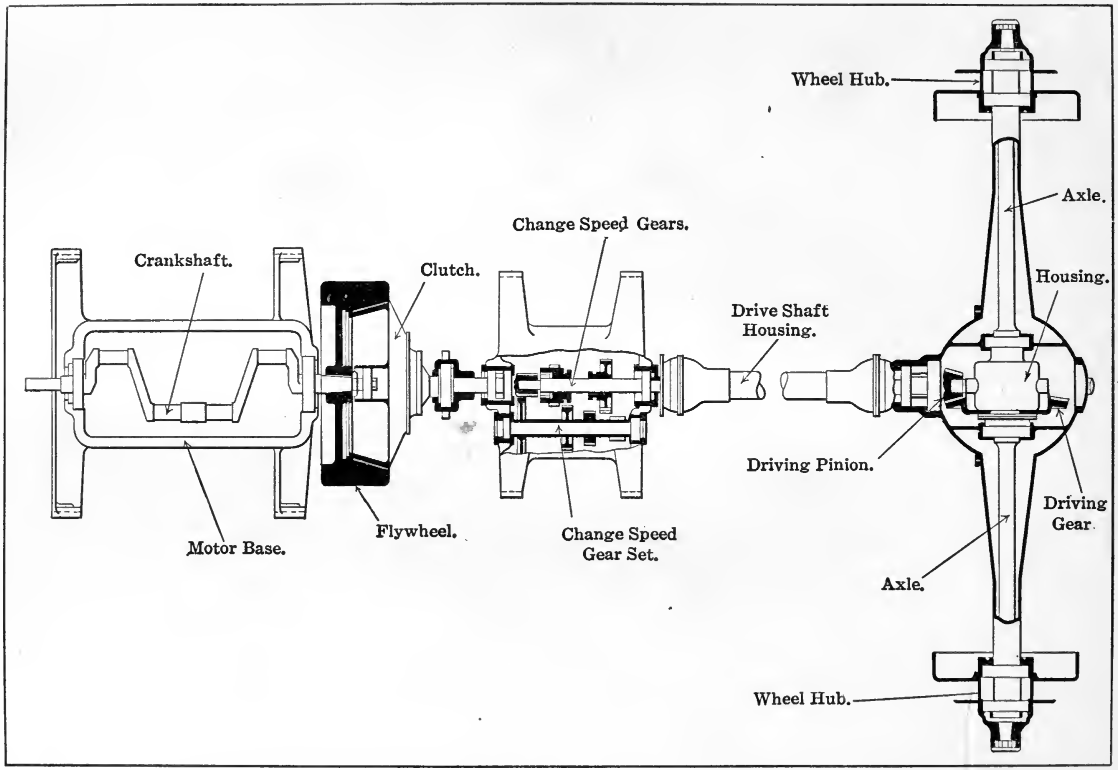


Fig. 234.—Plan of Components of Power-Transmission System of Typical Gasoline Automobile, Depicting Relation of Clutches, Gearset and Driving Gears.

and much experimenting was necessary before the perfected forms of the present day were evolved.

A typical power-transmission group such as employed in the modern gasoline automobile is depicted in Fig. 234. In this the power is applied to the crank shaft of the motor and from thence it is delivered to the motor fly wheel which forms the female member of a friction clutch. The male member of the clutch is coupled to the change-speed gearing and this in turn is joined to the driving pinion in the rear axle by a length of shaft. The driving pinion delivers its power to a bevel-driving gear which is carried by the differential casing in the rear axle housing. From the differential gear independent shafts or axles drive the rear wheel hubs.

The function of the clutch is to permit the engine to be run independently of the transmission gearing when desired. The engine can drive the car only when one of the sets of gears in the gearset and the clutch are engaged simultaneously. For example, if the clutch is out or released, even if the gears were in mesh in the change-speed device, the rear wheels would not be turned until the clutch cone was allowed to engage the female member formed in the fly-wheel rim. At the other hand, when the parts are as shown with the clutch in engagement and the speed gears out of mesh the engine can still be revolved without turning the rear wheels.

Why Clutch Is Necessary.—In order to secure a better understanding of the general requirements of clutching devices it will be well to consider the conditions which make their use imperative when a motor car is propelled by a hydrocarbon motor. If a steam engine or an electric motor are installed as prime movers it is not necessary to include any clutching device or gearset between them and the driving wheels, and these members may be driven directly from the power plant if desired. With either of the forms mentioned the power is obtained from a separate source which may be uncoupled from the motor by the simple movement of a throttle valve or switch lever. Steam and electric motors are also capable of delivering power in excess of their rating and are more flexible than internal combustion power plants.

If steam is the motive agent it is generated and contained in a special device known as a boiler, and the amount of power delivered by the engine to which the boiler is connected will vary with the amount of steam admitted and its pressure. If the steam supply is interrupted entirely the engine and the car which it drives are brought to a stop. When it is desired to start again a simple movement of the throttle-valve lever will permit the steam to flow from the boiler to the engine cylinders again and the vehicle is easily set in motion. If it is desired to reverse the car the steam flow is reversed by a simple mechanical movement and the engine will run in the opposite direction to that which obtains when the car is driven in a forward direction.

If an electric motor drives a vehicle the electrical energy is secured from a group of storage batteries. When these are fully charged varying amounts of electric current may be drawn from them and allowed to flow through the windings of the field or armature of the motor and different ratios of power or speed obtained. The vehicle is easily started by completing the circuit between the motor and the source of current and stopped by interrupting the supply of electrical energy. As the flow of electricity can be reversed easily by a switch the car may be driven backward or forward at will, and as the speed may be easily varied by changing the value of the current strength there is no need of speed changing or reversing gears.

When a gasoline engine is fitted, conditions are radically different than with either a steam or electric power plant. The power developed depends upon the number of explosions per unit time and the energy augments directly as the number of explosions and revolutions of the crank shaft increase. It is not possible to start a gasoline engine when under load because the power is obtained by the combustion of fuel directly in the cylinders, and as there is no external source of power to draw from it is obvious that the energy derived depends upon the rapidity with which the explosions follow each other. It has been demonstrated that a certain cycle of operation is necessary to secure gasoline-engine action and it is imperative that the engine revolves freely until it attains sufficient speed to supply the torque or power needed to overcome the resistance that tends to prevent motion of the car before it can be employed in driving the vehicle.

Then, again, it is very desirable that the vehicle be started or stopped independently of the engine. With a steam or electric motor the vehicle may be started just as soon as the driving power is admitted to the prime mover, but with a gasoline engine it is customary to interpose some device between the engine and driving wheels which make it possible to couple the engine to the wheels or driving gearing and disconnect it at will. The simplest method of doing this is by means of some form of clutching device which will lock the driving shaft to the crank shaft of the engine.

Clutch Forms and Their Requirements.—Clutch forms that have been applied to automobile propulsion are usually of the frictional type, though some have been devised which depend upon hydraulic, pneumatic, or magnetic energy. Those which utilize the driving properties of frictional adhesion are most common and have proven to be the most satisfactory in practical application. The most important requirement in considering clutch forms is that such devices must be capable of transmitting the maximum power of the engines to which they are fitted without any power loss due to slipping. Such a clutch must be easy to operate and but minimum exertion should be required of the operator. When the clutch takes hold the engine power should be transmitted to the gearset and driving means in a gradual and uniform manner, or the resulting shock may seriously injure the mechanism. When released it is imperative that the two portions of the clutch disengage positively so that there will be no continued rotation of the parts after the clutch is disengaged.

The design should be carefully considered with a view of providing as much friction surface as possible to prevent excessive slipping and loss of power. It is very desirable to have a clutch that will be absolutely silent whether engaged or disengaged. If the clutch parts are located in an accessible manner it may be easily removed for inspection, cleaning, or repairs. It is desirable that adjustment be provided, so a certain amount of wear can be compensated for without expensive replacement. A simple, substantial design with but few operating parts is more to be desired than a more complex device which may have a few minor advantages, but which is more likely to cause trouble.

The friction clutch in its various efficient types is the one that more nearly realizes the requirements of the ideal clutch. As a result this form is now universally recognized by automobile designers, and all standard gasoline automobiles utilize some form of friction clutch. These devices are capable of transmitting any amount of power if properly proportioned, and permit of gradual engagement and positive disconnection. Most friction clutches are simple in form, easily understood, and may be kept in adjustment and repair without difficulty.

How Friction Clutches Transmit Power.—To illustrate the transmission of power by the frictional adhesion of substances with each other we can assume a simple case of two metal disks or plates in contact, the pressure existing between the surfaces being due to the weight of one member bearing upon the other. If the disks are not too heavy, it will be found comparatively easy to turn one upon the other, but if weights are added to the upper member a more decided resistance will be felt which will increase directly as the weight on the top disk and consequently the pressure between the disks increases. It may be possible to add enough weight so it will be practically impossible to move one plate without turning the other. It is patent that if one of these plates was mounted rigidly on the engine shaft and one applied to the transmission shaft so that it had a certain amount of axial freedom and pressure of contact was maintained by a spring instead of weights, a combination capable of transmitting power would be obtained. The spring pressure applied to one disk would force it against the other and one shaft could not turn without producing a corresponding movement of the other.

Materials Employed to Increase Frictional Adhesion.—The main object of engineers in designing a clutch is to increase the amount of friction adhesion existing between the parts as much as possible. The transmitting efficiency of the clutch will vary with the coefficient of friction between the surfaces and the more the friction between them the more suitable the clutch will be for transmitting power. A metal usually forms one frictional surface in all forms of clutches, and some types have been designed and used successfully in which all friction surfaces are metals.

The materials of a metallic nature commonly used are cast iron, aluminum and bronze castings, and sheet steel and bronze, usually in the form of thin-stamped disks. The nonmetallic frictional materials generally used are leather, asbestos fabrics, textile beltings, and cork. Leather is the best lining or facing for clutches where the frictional area is large. When used it must be kept properly lubricated and soft, as if it becames dry it will engage very suddenly and clutch action will be harsh. At the other hand, care must be taken not to supply too much lubricant or the coefficient of friction will be reduced to a low point and the surfaces will slip. Oak-tanned leather is generally used because it has good wearing qualities, is a very resilient material, and possesses a very satisfactory degree of frictional adhesion when pressed against a cast-iron member. Asbestos fabrics are being applied in many forms of dry plate clutches and have been used to some extent in facing the male member of cone clutches. These are not as elastic as leather and unless some auxiliary-relieving member is employed they will grip suddenly and undesirable harsh clutch action obtain.

When cork is used it is inserted in the metal surface in suitable holes which are machined to receive the inserts. Cork possesses peculiar qualities which make it very suitable for use in a clutch. It has perhaps the highest coefficient of friction of any of the materials employed, is not materially affected by either excessive lubrication or lack of it, and possesses very desirable wearing qualities. A clutch fitted with cork inserts will engage gradually and power will be transmitted to the rear wheels without shock or jar. It is the lightest and most elastic of the solids. In application cork must be used as an insert, because it is too brittle to be used in sheet form with any degree of success.

When applied to a clutch the cork always works alone at low or medium pressures and at high pressures the other surfaces become engaged. This is given as the reason for the excellent wearing qualities of such combination surfaces, and when corks form a relatively large proportion of one of the contact surfaces they prevent cutting, no matter whether there is lubricant present or not. Then again, in the presence of a lubricant, which would obviously cause slippage between plain metallic or other surfaces, the corks so largely increase the total frictional adhesion that slippage is almost impossible.

Opinions vary among designers regarding the most suitable materials to use, though the selection of frictional material depends in most cases upon the type of clutch used. The large majority who favor the cone clutch employ a leather and cast iron combination and in many cases cork inserts are also employed. Metal to metal surfaces are the rule in multiple disk or plate clutches of small diameter, though as a general thing when a lesser number of plates of large diameter are used cork inserts or an asbestos fabric facing are invariably provided on one set of plates.

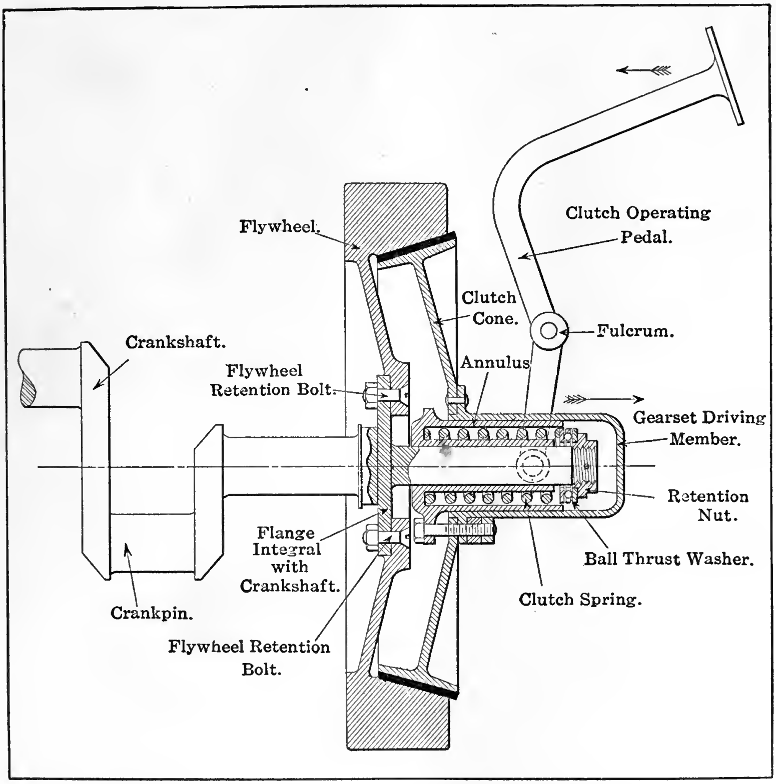


Fig. 235.—Sectional View of Cone Clutch Having Female Member Formed Integral with Fly-Wheel Rim.

Forms of Cone Clutches Outlined.—A simple and efficient form of cone clutch is shown at Fig. 235. This consists of three main parts, the female member, which is machined integral with the fly wheel, a corresponding male member, which fits into it, and a spring to maintain contact between the surfaces. The fly wheel is attached to a flange forged integral with the end of the crank shaft by suitable screws. The male member is a truncated cone of metal faced with leather. The female member may be machined integral with the fly wheel, as shown at Fig. 235, or it may be applied to the fly-wheel rim by means of bolts, as outlined at Fig. 236.

Experience has demonstrated that cast iron and leather make a very good wearing combination, and the tendency to use cork inserts to prevent harsh engagement is growing at the present time. Plain metal-to-metal surfaces are not suitable with this form because they would grip too suddenly and would soon slip if there was a thin film of oil between the surfaces. It will be noted that in either case frictional contact between the clutch cone and fly-wheel rim is maintained by the use of a coil spring which is backed by a ball-thrust bearing in order to relieve the operating mechanism of any torque strain when the clutch is disengaged.

In the cone clutch shown at Fig. 235, the male member is carried by a hub portion to which it is bolted, concentric with an annulus which bears on the crank-shaft extension. One end of the spring bears against the closed end of the annulus while the other end is held by the ball-thrust washer and nut screwed on to the end of the crank shaft. The spring pressure in this case keeps the cone seated by pushing it directly toward the crank shaft. When it is desired to release the clutch the operating pedal is depressed in such a manner that it swings on the fulcrum point and moves the clutch cone and the annulus member by which it is supported back so the clutch cone is pulled away from the fly wheel and the spring compressed. Some form of Oldham coupling or sliding joint is carried by the gearset driving member and is attached to the shaft extending from the gear case. When the spring pressure forces the clutch cone into engagement with the fly wheel, the assembly turns as a unit and the gearset is driven by the engine crank shaft through the medium of the clutch and the gearset driving member which is attached to the clutch cone. When the cone is pulled away from the fly wheel the annulus which carries the gearset driving member remains stationary and the crank-shaft extension revolves in it.

The clutch outlined at Fig. 236 differs from that previously shown in that the cone is inverted and the spring pressure is employed to

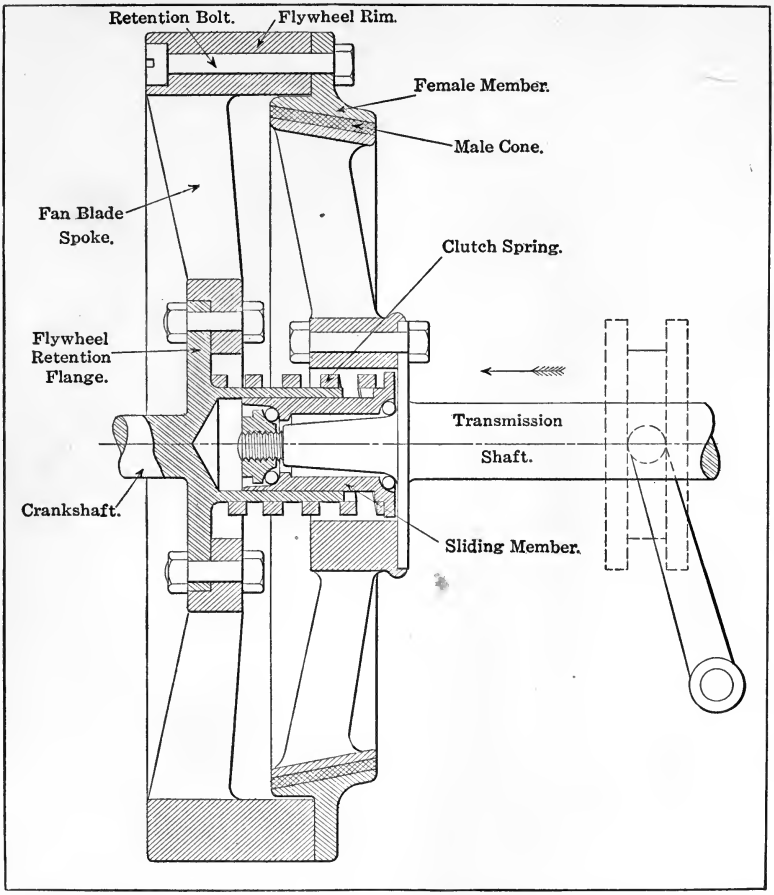


Fig. 236.—Cone Clutch Design with Female Member a Separate Casting Bolted to Fly-Wheel Rim.

push the cone away from the fly wheel to engage it. The cone is carried at one end of the transmission shaft and revolves idly when it is pushed toward the fly wheel so that it is not in contact with the female member. In the cone clutch previously described the female member was machined in the fly-wheel rim. In that outlined at Fig. 236 the female member is a separate casting bolted to the fly-wheel rim.

Typical designs of clutch cones and methods of fastening the friction facings to the cone castings are shown at Fig. 237. In that shown at A a combination of leather facing and cork inserts is employed. The leather is secured to the cast aluminum cone by means of rivets and the cork inserts are forced into recesses cast into the cone member. At B the practical method of retaining the leather facing employed on White automobiles is illustrated.

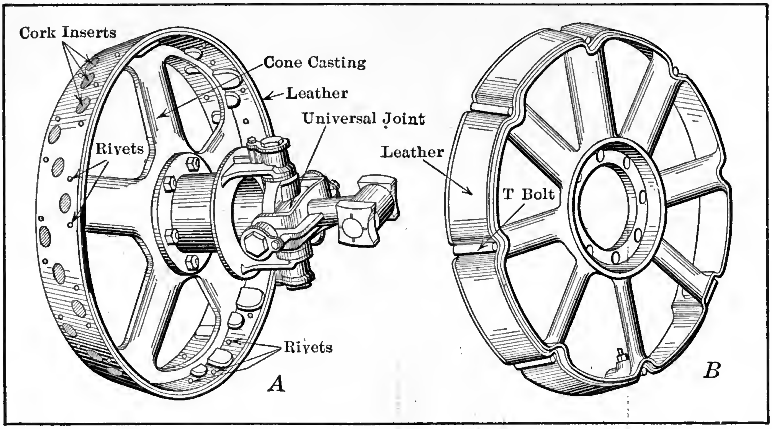


Fig. 237.—Typical Cone Clutch Male Members, Showing Methods of Attaching Leather Facing to Cone Casting. A—Pope-Hartford Clutch Cone Faced with Leather and Cork Inserts. B—White Cone Uses Leather Band Held in Place by T Bolts.

When the leather facing is riveted to the cone rim considerable labor is involved in removing it after it has worn to such a point that replacement is necessary because the large number of rivets must be driven out before the leather can be removed. The leather band which forms the friction facing of the cone at B is held by a number of T head bolts which pass through the cone rim and which seat into longitudinal grooves cast into the periphery of the cone member. These are of sufficient depth to prevent the heads of the bolts rubbing against the female member of the clutch and only the leather facing acts as a driving surface. When the leather becomes worn it is a comparatively simple matter to remove the T bolts and put a new leather band in place.

On some cone clutches of European design the endeavor has been made to use metal-to-metal surfaces by housing the cone in an oil-

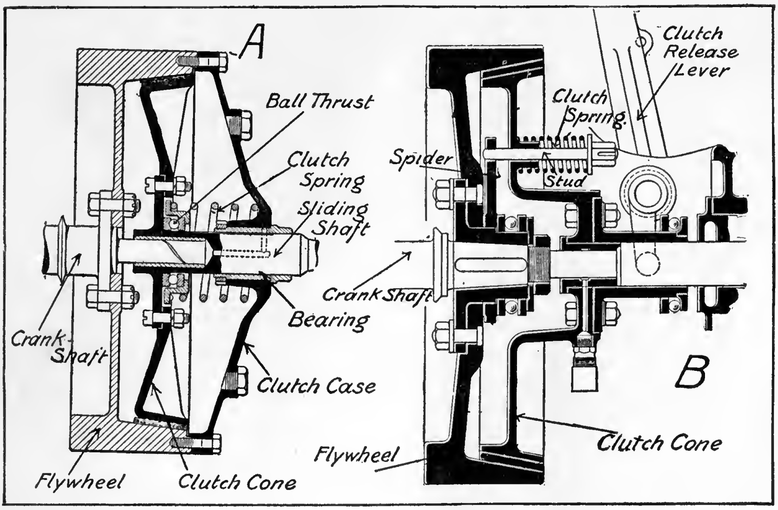


Fig. 238.—Cone Clutches of English Design. A—Metal-to-Metal Surfaces in Oil-Tight Case. B—Method of Holding Parts in Contact with Adjustable Springs.

tight casing so that it worked in a bath of lubricant. The lower co-efficient of friction existing between lubricated surfaces is compensated for by increasing the spring pressure. Such a clutch is shown in section at Fig. 238, A. The clutch case is formed of two members, one of these being the fly wheel, which is attached to the crank-shaft flange by bolts, the other is a cast casing, which is bolted to the fly-wheel rim on its face. The clutch cone is attached to a sliding shaft which telescopes on to the projecting end of the crank-shaft extension and which slides through an oil-tight bearing carried by the clutch case which is bolted to the fly-wheel rim. The spring thrust is taken at one end by the clutch casing and bears against a ball-thrust washer which seats against the flange to which the clutch cone is attached. The female member is machined in the fly wheel and does not differ from conventional forms.

Another form of English derivation is shown at Fig. 238, B, this differing from those previously described only in the method of applying the spring pressure. A three-arm spider carries three studs spaced at 120 degrees which also pass through bosses on the clutch cone. The spider is kept in place by a ball-thrust bearing retained on the fly-wheel hub by a clamping nut screwed on a thread cut at the end of the fly-wheel-retaining member which serves to keep the fly wheel in place, as well as forming a backing for the thrust bearing. The studs which project through the clutch cone have nuts threaded on the outer ends, and a spring is mounted outside of each clutch cone boss in such a way that it presses against the nut on the end of the stud and presses the cone into engagement with the fly wheel. The drive is interrupted by pulling the cone out of engagement in the usual manner.

One of the disadvantages of the cone clutch, unless it is exceptionally well designed, is that it is likely to engage harshly if the leather facing becomes charred or hard from any other cause. When cork inserts are used in connection with the leather, a more gradual engagement is secured, even when the leather is dry, than would be possible without their use. Some designers have sought to secure easy engagement by using a number of auxiliary friction pads attached to the cone periphery, while others have been satisfied to use springs under the clutch leather which would raise it at a number of points around the periphery of the clutch cone. The object of this is to have a limited area of the leather surface engage the female member before the full spring pressure is exerted to bring the entire frictional surface in contact.

The clutch shown at Fig. 239, which has been used on Columbia automobiles, is a conical type having a number of auxiliary friction pads extending through the periphery of the cone and projecting slightly above its surface. These are kept in place by auxiliary springs of the coil type. When the clutch cone is first engaged these friction shoes will engage the surface of the female member at a number of points and then when full spring pressure is exerted it will overcome the resistance of the small radial springs and the friction blocks will be depressed so they will be flush with the surface of the male member which then takes the drive.

The cone clutch is one of the most popular forms and has received general application, and its simple construction enables the motorist to easily understand its action. As there are but few parts there is but little liability of the cone clutch giving trouble if the leather

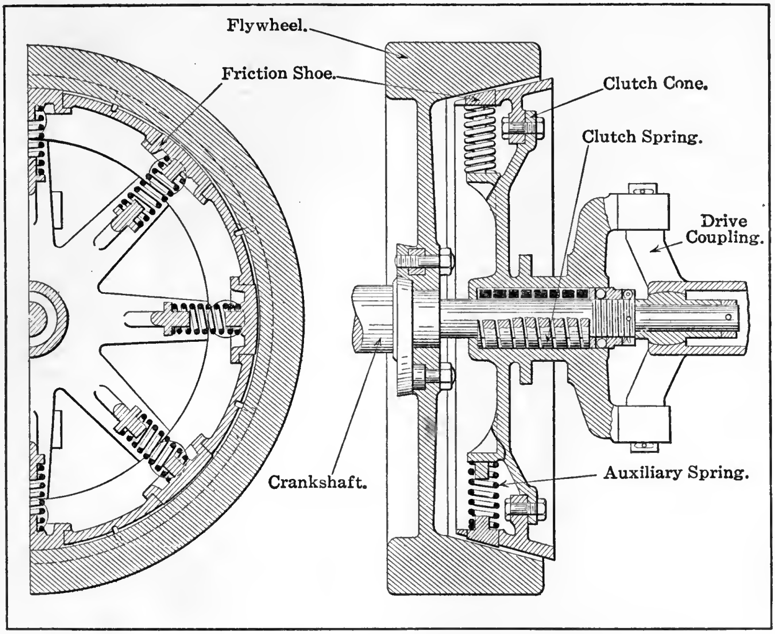


Fig. 239.—Columbia Clutch Employs Friction Shoes to Grip Fly Wheel Before Cone is Fully Engaged, to Secure Gradual Application of Power.

surface is kept in proper condition. The chief disadvantage advanced against cone clutches is that they are more bulky than other forms of equal capacity. The large size of the members of a cone clutch tend to make it "spin" after it is disengaged. The natural tendency of a body in motion is to continue in motion until stopped by some external force, which property is known as "inertia."

If two wheels of the same weight are set in motion by the expenditure of equal amounts of energy the one that has the weight carried nearer the rim or which is larger in diameter will revolve the longest. The male member of a cone clutch, when released, will have a tendency to continue to revolve even when the driving pressure is relieved. When sliding gearsets are employed to obtain the various speed ratios it is imperative that the engine be entirely disconnected from the main shaft of the change-speed gearing before any attempt is made to shift the gears. If the sliding members are moved without first disconnecting the shafts from the engine it would be very difficult to engage them and it might result in stripping the teeth from the gears.

The average cone clutch is of large diameter if much power is to be transmitted because the two surfaces in contact are comparatively narrow. When the clutch is released considerable energy has been stored in the rim of the cone and its tendency is to keep revolving and carry the shaft of the gearset to which it is attached at the same speed. In some cases it is difficult to shift the gears until the motion of the shaft ceases and it is either necessary to wait until the momentum of the clutch cone becomes less or to apply some form of brake which will stop the cone from rotating. Such brakes are usually interconnected with the foot pedal and act only when the clutch is fully disengaged.

Cone-clutch efficiency depends on a number of factors, chief among which is the angle of the cone. The greater the angle the more spring pressure required because the wedging effect of a large angle is not as pronounced as when more gradual tapers are employed. Most cone clutches have the cone tapering at an angle of 12½ degrees and is not considered good design to use a lesser angle because the wedging effect may make it extremely difficult to release the clutch. At the other hand, angles much greater than 15 degrees make it necessary to use excessive spring pressure to maintain proper frictional adhesion between the parts.

Three- and Five-Plate Clutches.—A number of cars are provided with clutches composed of three or more plates of large diameter instead of the use of two cone members. It is claimed that these forms make for very easy engagement and that they will give a very prompt releasing action when the surfaces are separated. The usual construction is to use two driving members which are carried around by the fly wheel which clamp against a central-driven member which drives the gearset shaft. These clutches are very effective, but one of the chief disadvantages is the same as that advanced against the cone clutch and that is the inertia of the driven member when released. When these clutches are fitted it is desirable that they be provided with some form of a brake to bring them to a stop as soon as disengaged.

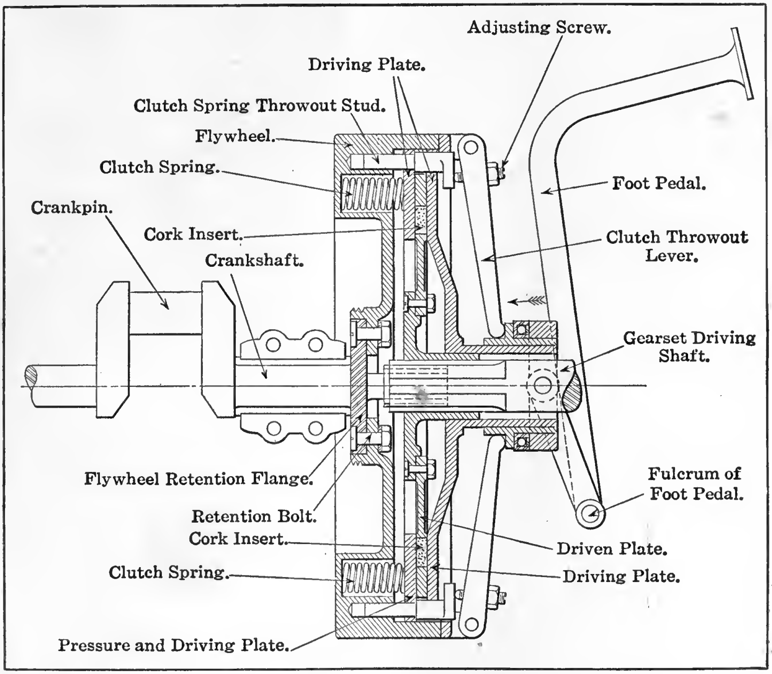


Fig. 240.—Three-Plate Clutch Utilized on Knox Motor Cars Uses a Central Driven Plate Studded with Cork Inserts.

A three-plate clutch which has been used successfully on Knox automobiles is shown at Fig. 240. In this construction the clutch springs are spaced at equal distances around the periphery of the fly wheel and bear against a pressure plate which is carried around by studs placed just outside the springs. Two driving plates are provided and these clamp a single-driven member attached to a revolving sleeve to which the gearset driving shaft is keyed. The pressure of the springs against the pressure plate holds the driven plate firmly against the outside driving plate. When it is desired to release the clutch the pedal is depressed and it pushes the clutch throw-out levers toward the fly wheel so the clutch spring throw-out studs push the pressure plate away from the driven plate and allow it to revolve independent of the clutch. The clutch throw-out studs perform a double duty in that they also act as driving members for the two driving plates. The driven plate is provided with a large number of cork inserts to increase its frictional adhesion.

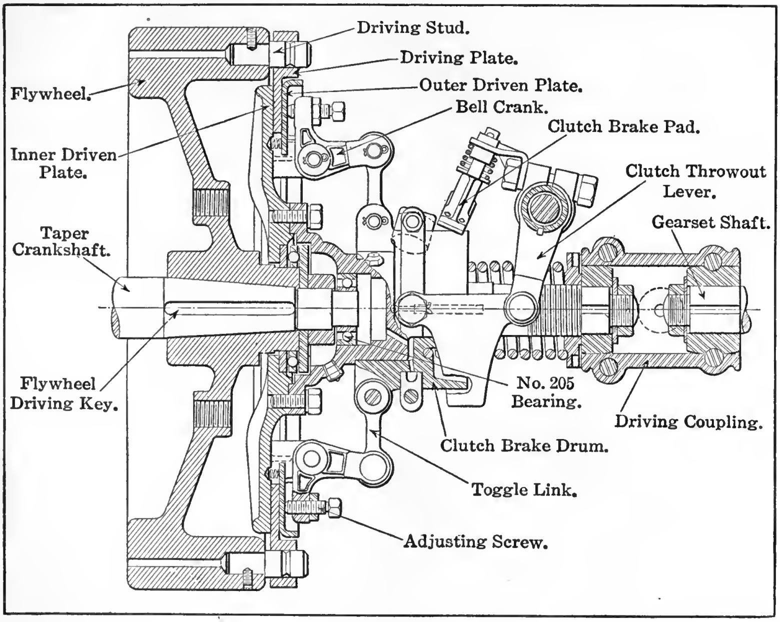


Fig. 241.—A Three-Plate Clutch Equipped with Friction Brake to Arrest Motion of Driven Member when Clutch is Released.

Another form of three-plate clutch in which there are two driven plates and one driving member is shown at Fig. 241. The driving plate is carried around by a number of studs spaced around the fly-wheel-rim face. The driven member nearest the fly wheel carries a number of arms to which small bell cranks are fulcrumed. These

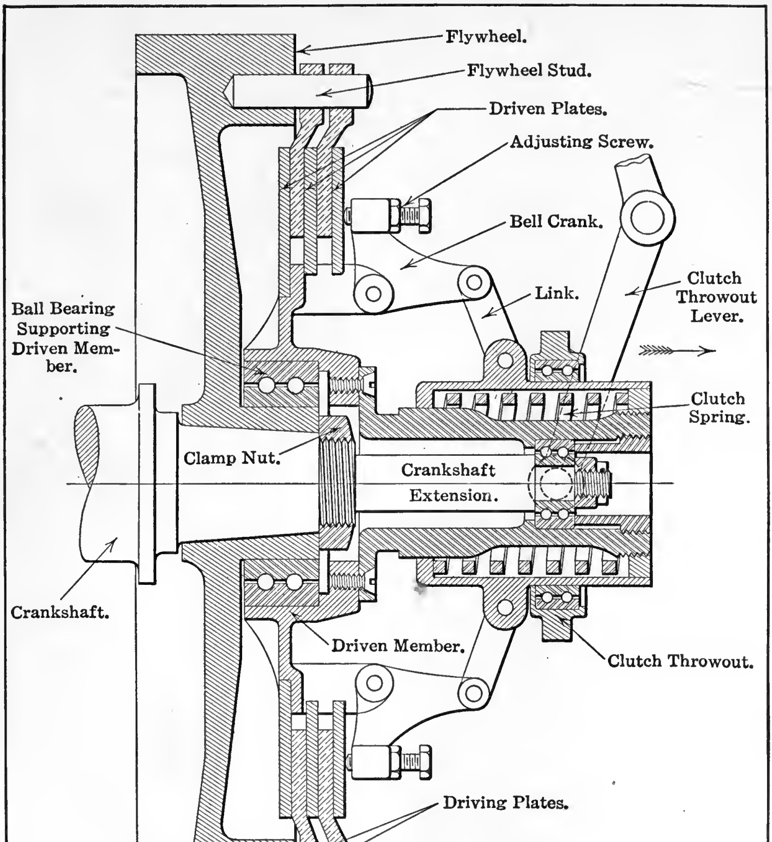


Fig. 242.—Five-Plate Clutch which Employs Two Driving Members Attached to Fly Wheel and Three Driven Plates.

arms also act as a support for the outer driven plate. The clutch spring bears against a sliding member which forces the ends of the bell crank to which it is connected by a series of toggle links outwardly, and clamps the driving plate firmly between the inner and outer driven plates. When the clutch spring is depressed the bell cranks drop back and the pressure between the driving plate and the faces of the driven members is relieved. When this condition exists the driving plate turns with the fly wheel but does not produce movement of the driven members to which the gearset shaft is attached by a semiuniversal driving coupling. When the clutch throw-out lever is moved away from the fly wheel to release the clutch it brings a small brake pad in contact with a drum carried by the driven member and stops its rotation. When the parts are as shown in illustration, the driving plate is firmly clamped between the driven members and the power of the engine is being transmitted directly to the gearset shaft.

In order to obtain more driving surface some designers have used five plates instead of three. A five-plate clutch which operates on the same general principle as the three-plate type previously described is shown at Fig. 242. In this, two driving plates are carried by studs set into the fly-wheel face and the three driven members are kept in engagement by means of bell cranks and toggle-link action. The reason that five disks are used instead of three is that the augmented surface makes it possible to reduce the spring pressure to some extent and makes for easier operation when it is desired to disengage the clutch. When the driving contact between the clutch plates is interrupted the member to which the gearset shaft is attached is kept stationary and the fly-wheel hub and crank-shaft extension revolve freely because anti-friction bearings of the ball type are interposed between the members.

Features of Multiple-Disk Clutches.—Power transmission by plates is sometimes accomplished by using a large number of small diameter disks instead of the smaller number of large plates. The multiple-disk type offers several advantages not found in other forms, as it is the most compact form of clutch. The required contact area is obtained by using a multiplicity of comparatively small surfaces in preference to two large ones as is the case with the cone clutch or the greater number possible when three- or five-plate clutches are employed.

The type of multiple-disk clutch that seems to be most widely employed consists of a number of soft steel disks which sometimes alternate with others of different material such as phosphor bronze. One set of these disks is driven by the engine while the remaining plates are attached to a floating member to which the transmission shaft is joined. Pressure is usually obtained from a coil spring which acts against one of the disks, which in turn acts upon the neighboring one. It is common practice to house a clutch of this type in an oil-tight case, which insures that the members will always be kept in an oil bath. Oil performs the dual function of securing easy engagement by interposing a cushion between the metal elements and also to prevent wear because of its value as a lubricant.

As multiple-disk clutches are usually of small diameter, the inertia of the driven member is small compared to that of a cone or large plate type, and the spinning tendency is reduced. The spring pressure is usually sufficient to squeeze the oil from the plate as soon as engagement is fully made and a metal to metal contact then obtains. The fact that the lubricant is gradually forced out and that there will be a certain amount of slipping as long as any of the lubricant remains means that the power will be applied in a gradual manner even if the clutch is carelessly operated.

While a multiple-disk clutch does not have a tendency to spin because of inertia, the plates may sometimes refuse to disengage because of a partial vacuum existing between them, produced when the oil film was forced out. This sometimes causes the plates to adhere together. This trouble is rare in well-designed clutches and is seldom present unless poor lubricating oil is used between the plates. This drag and consequent trouble in shifting gears is more apt to occur on forms which employ flat-stamped plates without spring tongues to separate them when the spring pressure is relieved. Multiple-disk clutches are sometimes provided with plates having cork inserts, while others have a number of the disks faced with some friction material such as the asbestos-wire fabric and are designed to run dry instead of in an oil bath.

A typical multiple-disk clutch is shown at Fig. 243. In this member the clutch case is cast integral with the fly wheel and forms the fly-wheel hub. A series of disks are carried by a driving drum and are kept in engagement with those carried around by the fly wheel by means of pressure derived from a coil spring which is let into a bored-out recess at the end of the crank shaft. The clutch depicted is intended to run in oil and a number of the plates are

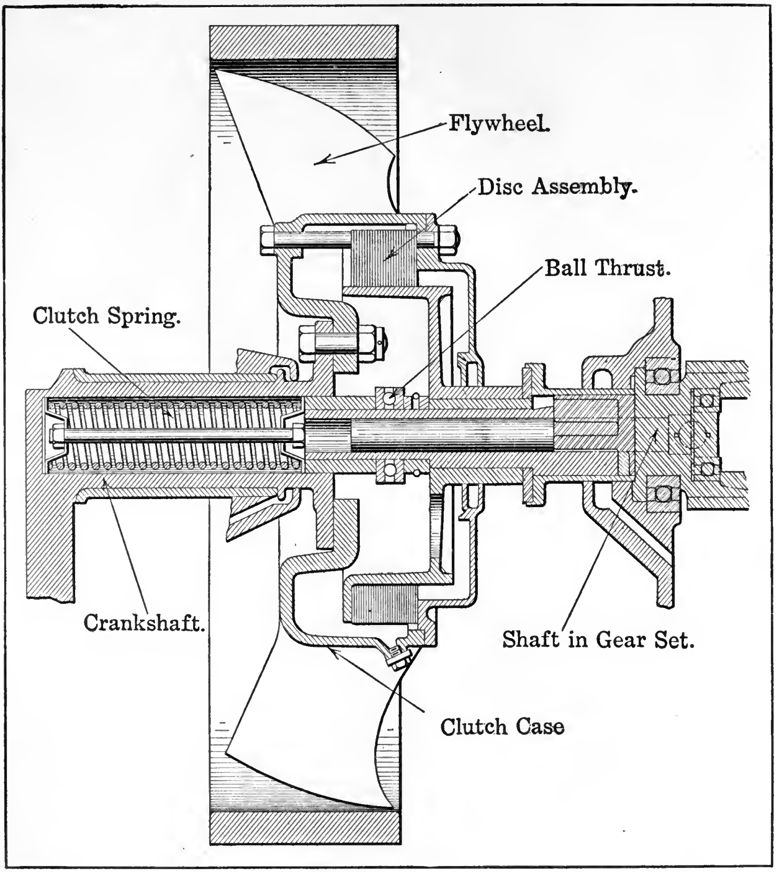


Fig. 243.—Typical Multiple-Disk Clutch Assembly. The Form Illustrated is Used on Some of the Hudson Cars.

provided with cork inserts. The multiple-disk clutch depicted at Fig. 244 is that used on Franklin cars, and is a form in which all metal plates running in oil are used. That depicted at Fig. 245 is

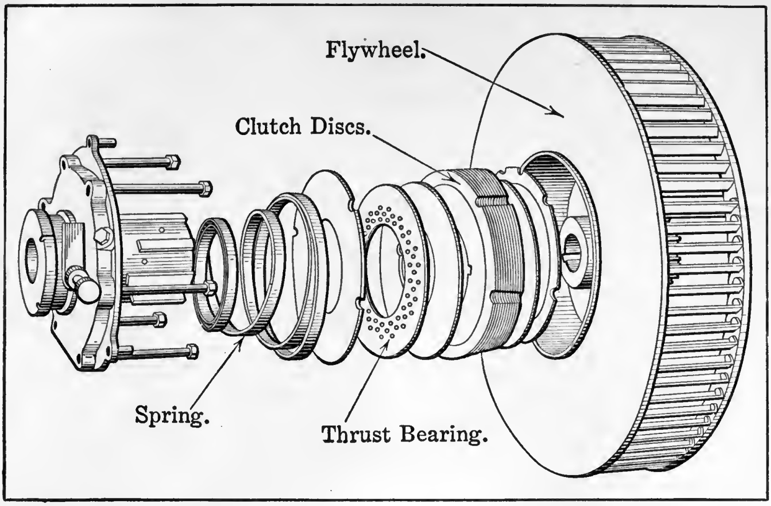


Fig. 244.—Multiple-Disk Clutch Utilized on Franklin Automobiles is Housed in Blower Fly Wheel. Parts are Shown Separated to Make Construction Clear.

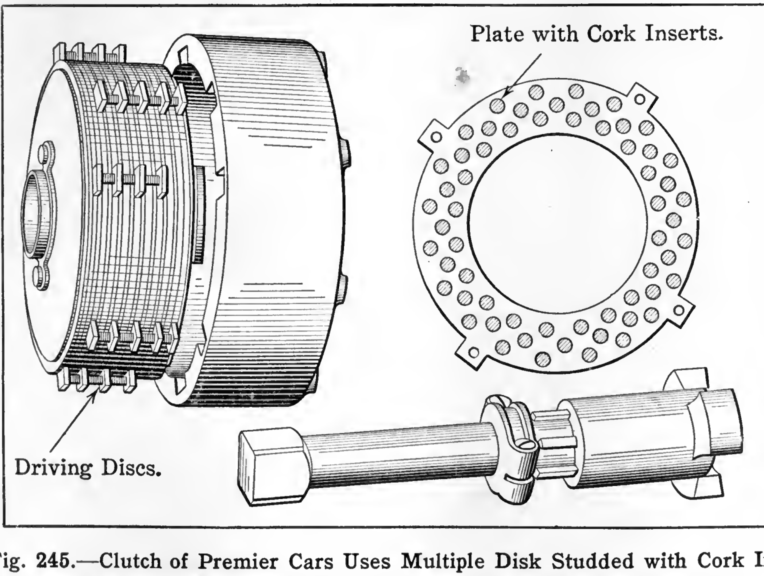


Fig. 245.—Clutch of Premier Cars Uses Multiple Disk Studded with Cork Inserts as Driving Members, and Plain Metal Plates as Driven Elements.

used on Premier cars and one set of plates is provided with a large number of cork inserts to promote easy engagement, positive drive, and prompt release.

While the clutch forms described are the most common, a few cars have been provided with internal expanding band clutches or external constricting band forms. The internal member consists of a steel band or shoe faced with leather or other frictional material or provided with cork inserts which expands against the inner periphery of a drum integral with the fly wheel. The band is expanded by spring pressure which spreads the driven member either by toggle linkage or a right and left hand quick-acting screw.

Planetary gearsets employ external constricting bands to stop rotation of the gear drums, but these should properly be considered under the head of brakes rather than clutches. The disadvantage of either internal or external band clutches is that they are very hard forms to balance and the internal expanding band is especially susceptible to the influence of wear and oil between the surfaces. The external band provides a very gradual clutching action, but owing to the difficulty in balancing it because of the unsymmetrical operating mechanism usually employed, it has not been used to any extent in this country. With the forms described no difficulties are present as relates to balancing, and as the band forms have no apparent advantages when compared to the better developed cone and plate types there seems to be no reason for further development of forms which are good in theory but hard to apply in a practical manner.

Why Change-Speed Gearing is Necessary.—Those who are familiar with steam or electricity as sources of power for motor vehicles may not understand the necessity for the change-speed gearing which is such an essential component of the automobile propelled by internal combustion motors. In explaining the reason for the use of the clutch it has been demonstrated that steam or electric motors were very flexible and that their speed and consequently the power derived from them could be varied directly by regulating the amount of energy supplied from the steam boiler or the electric battery, as the case might be.

If, for example, we compare the steam motor with the explosive engine it will be evident that the power is produced in the former by the pressure of steam admitted to the cylinders as well as the quantity and the speed of rotation. When the engine is running slowly and a certain amount of power is needed more steam can be supplied the cylinders and practically the same power obtained as though the steam pressure was reduced and the engine speed increased. The internal combustion motor is flexible to a certain degree, providing that it is operating under conditions which are favorable to accelerating the motor speed by admitting more gas to the cylinders. There is an arbitrary limit, however, to the power capacity or the mean effective pressure of the explosion, and beyond a certain point it is not possible to increase the power by supplying vapor having a higher pressure as is possible with a steam engine.

In an explosive motor we can increase the power after the maximum throttle opening has been reached only by augmenting the number of revolutions. Whereas it is possible to gear a steam engine or an electric motor directly to the driving wheels, it is not possible to do this with a gasoline engine, and some form of gearing must be introduced between the motor and the driving wheels in order that the speed of one relative to the other may be changed as desired and the engine crank shaft turned at speeds best adapted to produce the power required, and to allow the rear wheels to turn at speeds dictated by the condition of the roads or the gradients on which the car is operated.

It is customary in all automobiles of the gasoline-burning type, where combustion takes place directly in the cylinders, to interpose change-speed gearing which will give two or more ratios of speed between the engine and the road wheels. As it is not possible to reverse the automobile engine utilized in conventional cars, it is necessary to add a set of gears to the gearset to give the wheels a reverse motion when it is desired to back the conveyance.

Many methods of varying the ratio of speed between the engine and traction members have been evolved, but few speed-changing mechanisms have survived. At the present time the majority of automobile makers employ sliding gear transmissions which are almost invariably of the selective type. One or two cars are fitted with simple face friction gearing and a limited number provide two forward speeds and a reverse motion by using planetary gearing.

At one of the recent automobile shows held at New York, 385 models of cars were exhibited, and of this number but a very small percentage used change-speed gearing that differed radically from standard practice. Of this number 347 models were equipped with selective sliding gear transmissions and six cars used progressive sliding gearing. Thirteen models utilized planetary transmissions and friction change-speed gearing was supplied in nineteen instances. While the sliding gear form of transmission is without doubt the most unmechanical and brutal of all speed gearing, if considered from a purely theoretical viewpoint, the very satisfactory service which is secured in actual use justifies its general application, especially at the present time when engineers are so thoroughly conversant with details of design and motor-car drivers have been so well trained to operate gears of this character with proper care.

Face Friction Gearing.—A form of gearing that has many adherents because of its simple design and easy operation employs two friction disks which are held together by sufficient pressure to cause

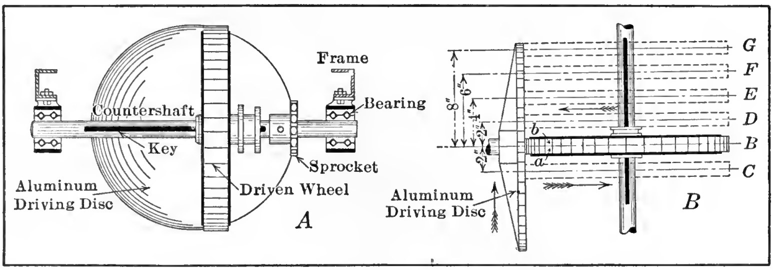


Fig. 246.—Outlining Action of Simple Face Friction Gearing, which Combines Clutching and Speed-Changing Functions.

one of these members to turn the other. This was one of the earliest forms of gearing used, and while it was abandoned for a time because of defects of a purely technical nature continual experiments made possible a combination of materials which gave satisfactory results in practice.

The rolling traction, or friction transmission, as it is commonly called in its simplest form, is shown at Fig. 246, A. It consists of two disks or plates, one faced with an aluminum-copper alloy driven by the engine and a wheel which is provided with a strawboard fiber driving ring mounted on a cross shaft at right angles to the crank shaft of the power plant. The cross shaft is journaled in anti-friction bearings and the driven disk or plate can be moved axially so as to engage with different portions of the aluminum driving disk. The driving member is mounted on a sliding shaft which can be moved toward the driven member and held in contact by a definite amount of pressure or pulled away when it is desired to interrupt the drive. In this manner both clutching and speed-changing functions are combined in one simple mechanism.

The method by which various speed changes may be secured is demonstrated at Fig. 246, B. The driven member is shifted across the face of the driving disk so it can engage different portions at varying distances from the center. As the wheel is moved from the center toward the outer periphery the speed ratios increase in proportion to the amount the disk is moved out. If the driven disk is moved over to the other side of the driving disk and past the central point a reverse motion will be obtained when driving contact is again established between the surfaces. To interrupt the drive the members are separated and when the faces are brought together the frictional adhesion permits one to drive the wheels.

Assume that both disks are sixteen inches in diameter and that the driven member has moved away from center until it engages a point having a mean radius of two inches from the center line. The disk would be moved from position B in which it is placed, as shown in illustration, to position indicated by the dotted rectangle D. In this case the driving effect would be just the same as though a four-inch diameter wheel was engaged with the sixteen-inch diameter driven member. This would give a low gear ratio because the engine would be turning at four times the speed of the driven member. If driving contact was again broken and the driven wheel moved along the shaft until it occupied the position indicated by the rectangle E, the effect would be the same as though an eight-inch driving member was turning the sixteen-inch driven wheel. This would give a higher ratio than in the case previously described, as the engine shaft would only turn at twice the speed of the driven member.

If the driven member was moved so that it occupied position G, the highest speed would be obtained because the disks would be turning at equal speed as one sixteen-inch wheel would be turning another one of the same diameter. If the disk was moved back to the other side of center or from position B, to that shown by the rectangle C,

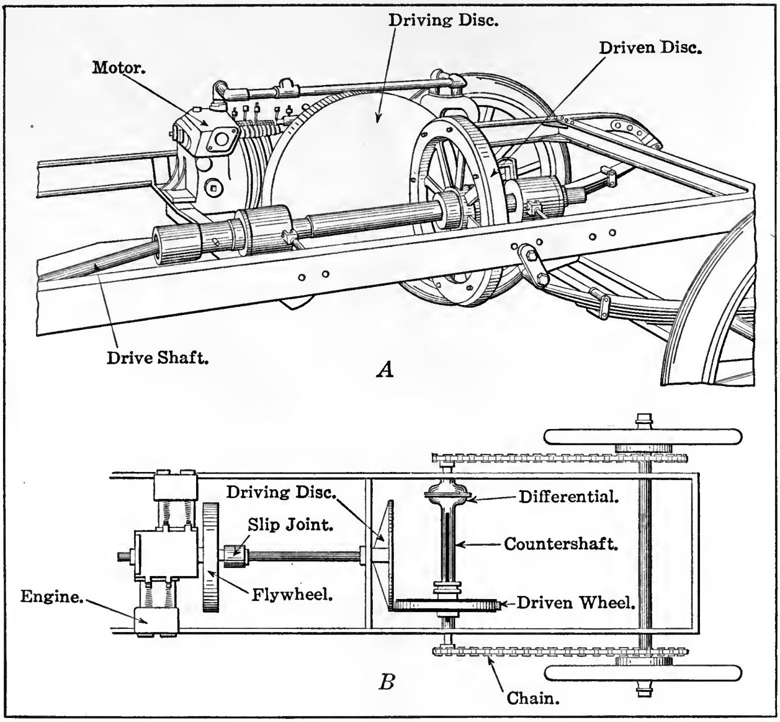


Fig. 247.—How Face Friction Gearing is Installed in Motor-Car Chassis. A—Arranged for Shaft Drive. B—Power Transmitted to Wheels by Side Chains.

the driven wheel would be turned at one fourth the engine speed and in a reverse direction.

This form of gearing is not generally used for high-powered cars because the driving wheel must be of large diameter and very bulky to transmit the higher powers. The amount of energy it is possible to transmit efficiently depends upon the nature and size of the surfaces in contact and the amount of pressure which is exerted to bring the friction members together. When a friction transmission is used it is usually applied in connection with single- or double-chain drives to the rear wheels, though forms have been devised where driving by shaft and bevel gears is possible.

The application of a friction transmission to a shaft-drive chassis is shown at Fig. 247, A. In this the double-opposed motor is mounted so the crank shaft is at right angles to the frame side member while the cross shaft on which the driven disk slides is parallel with the frame side. The aluminum-alloy driving disk is attached directly to the fly wheel of the motor, while the fiber-faced friction wheel is carried on a countershaft so journaled that the entire shaft may be swung over and bring the driven disk in contact with the driving member. A shaft serves to connect the driven disk shaft to bevel gearing in the rear axle.

At Fig. 247, B, the method of installation when a double-chain drive is provided is shown, while at Fig. 248 the layout of a friction gearing employing single-chain drive is outlined. The relation of the parts to each other can be very easily understood by referring

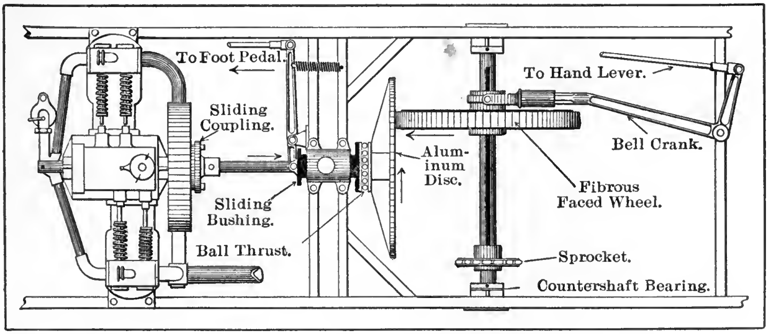


Fig. 248.—Disposition of Important Elements of Simple Face Friction Gearing Adapted for Single-Chain Drive.

to the illustrations. In the system depicted at Fig. 248 the double-cylinder engine is placed in the frame in such a way that the crank shaft is parallel with the frame side member. The drive from the engine crank shaft is through a sliding coupling at one end of the shaft which carries the aluminum driving disk. This member is backed by a ball-thrust bearing which in turn forms part of a sliding sleeve or bushing connected to the small arm of a lever which is joined to the foot pedal. When the long arm of the lever is moved in the direction of the arrow the sliding coupling is pushed in a reverse direction and the pressure exerted against the aluminum disk brings it in contact with the fiber-faced wheel on the countershaft. The driven wheel is moved along the countershaft by means of a long bell crank, the short end of which goes to the control lever while the long end is employed to swing the fiber-faced wheel along the countershaft. The drive from the countershaft is by means of chain and sprocket connection with a live rear axle.

In the form shown at Fig. 247, B, the rear axle is a stationary member and the wheels are driven independently by means of sprockets carried by the axle shafts of the compound countershaft, which is in reality a live axle mounted on the frame members and carrying the differential gear. As the power transmitted is directly proportional to the pressure maintaining contact between the surfaces it is imperative that the leverage employed to produce this pressure be very substantial and rigid. Tests have demonstrated that the best combination of surfaces is a strawboard fiber driving ring against an aluminum or copper-alloy driving plate, and these are the materials commonly used.

This form of gearing has the advantage that it is easily handled by the novice and it is difficult to injure it by careless manipulation. The number of forward speeds provided are infinite, as the driven member may be moved across the driving face very gradually and engage driving circles which vary by small increments. The surfaces must be kept clean and free from grease or the gearing will slip, and for this reason this form is not so generally used as one might suppose, if its value was judged only by its simplicity and ease of operation.

How Planetary Gearing Operates.—The planetary or epicyclic transmission is an easily operated form of speed gear that has been very popular on small cars. This has many features of merit, it provides a positive drive, and as the gears are always in mesh these members cannot be injured by careless shifting. Individual clutches are used for each speed and as the operation of the clutch occurs at the same time that the desired speed is selected the various speed changes desired may be easily effected by manipulating a single lever if desired.

A typical planetary gearing of simple form which was formerly used on Oldsmobile cars, which were one of the earliest makes to

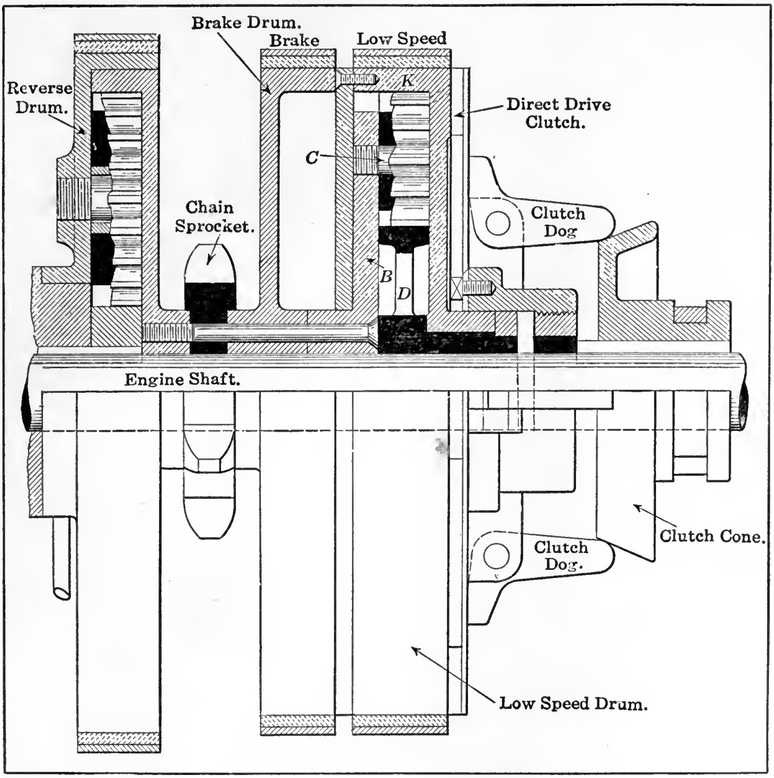


Fig. 249.—Sectional View of Simple Planetary Gearset.

be manufactured in large quantities, is outlined at Fig. 249. The gearing is carried in drums which are adapted to be revolved independently of each other or to be clamped by some form of clutch which would cause them to revolve as a unit with the crank shaft.

The drive is by single chain from a sprocket carried between the brake and reverse drum and the gearing was mounted on a crankshaft extension which projected from the fly wheel of the motor. The drum nearest the fly wheel carries three pinions which mesh with

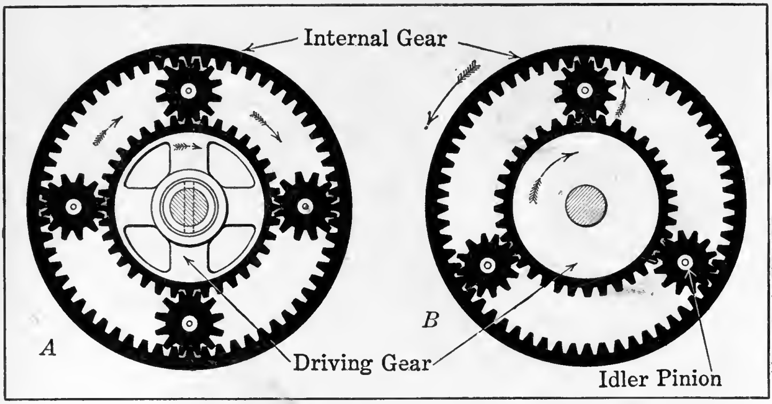


Fig. 250.—Demonstrating Action of Epicyclic Gearing. A—The Slow-Speed Gear Assembly. B—Gears and Pinions Used for Reverse Drive.

an internal gear member secured to the sprocket and with a gear driven by the fly-wheel hub. The slow-speed drum is provided with four pinions which are carried around by a disk which is also secured to the driving sprocket. In the reverse gear combination the disk that carried the pinions was provided with the brake member, while in the slow-speed gearing it was the internal gear which was held from turning when the slow-speed ratio was desired.

The master clutch, which provided the direct drive, consisted of four fingers provided with leather friction pads which were forced against the face of the internal gear drum of the slow speed by means of clutch dogs expanded by a sliding cone. When the clutch cone was forced in so that the small bell cranks brought the friction pads in contact with the face of the slow-speed drum, the entire assembly was firmly locked to the crank shaft and a direct drive obtained as the sprocket turned at the same speed as the engine shaft.

The method by which the slow and reverse speeds may be obtained and the arrangement of the planetary gearing is clearly shown at Fig.

250. At A the slow-speed gearing is shown while the reverse gear arrangement is outlined at B. The driving gear or center member in both cases is keyed to and turns with the crank shaft. With the combination shown at A, when the slow speed is desired the internal gear is kept from revolving by means of a constricting brake band which grips its outer periphery, and the small planetary pinions are forced to turn around on their supporting studs and carry the disk by which they are supported and which is attached to the driving sprocket in the same direction as the main driving gear, but at a slower speed. The gear reduction obtained depends upon the ratio of the driving and internal gear members.

When the reverse gearing is desired the mode of operation is different. The conditions are then as shown at B. In this case it is the disk carrying the pinion-supporting pins which is kept from rotating. The driving gear turns the idler pinions in a reverse direction, and these in turn cause the internal gear to which the sprocket is fastened to turn in a direction opposite to that of crank-shaft rotation and at considerably lower speed.

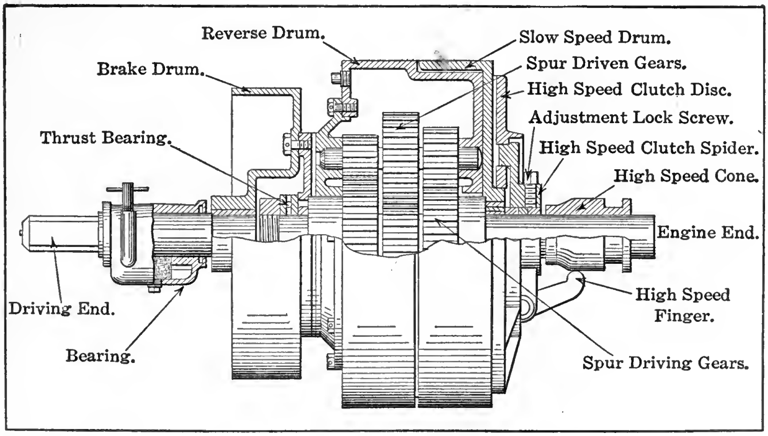


Fig. 251.—Planetary Gearing Utilizing Only Spur Gears Carried in Oil-Tight Case.

Other forms of planetary gearing have been evolved in which the internal gears have been eliminated and in which the gear ratios are provided by a train of spur gears. A gearset of this form is shown at Fig. 251, and as all parts are clearly indicated it will not be necessary to describe its action in detail because it is very much the same as that of the form previously described. When the slow speed is desired a brake band is clamped around the slow-speed drum,

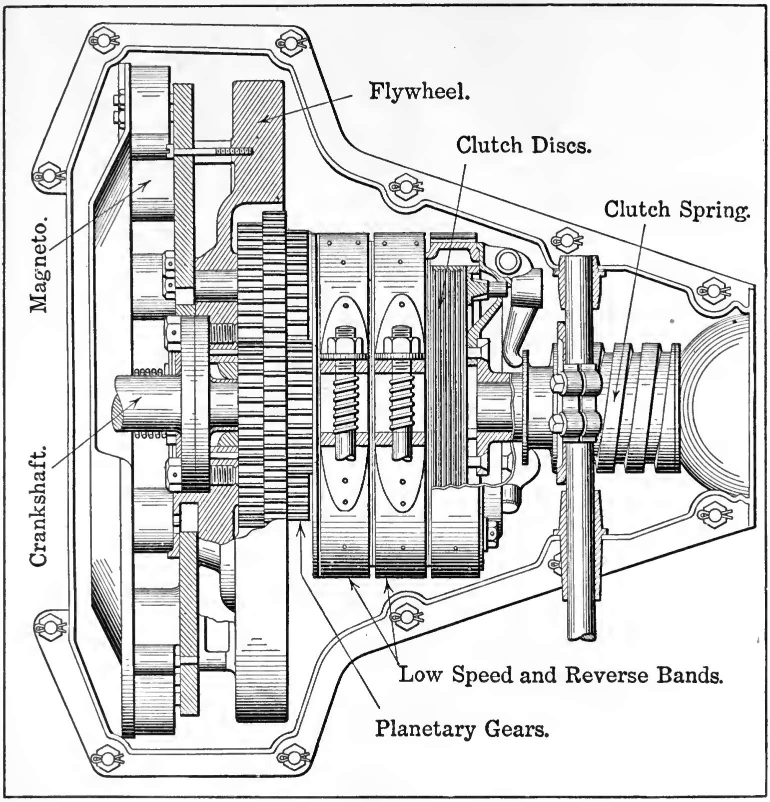


Fig. 252.—Two-Speed and Reverse Planetary Gear Employed on Ford Automobiles.

and a similar member constricted around the reverse drum will give the reverse motion. The gearing is locked together by means of a face-friction clutch, which is pressed in contact with the slow-speed drum face by means of a high-speed locking cone and cone-operated dogs or bell cranks. The form shown is intended to work in connection with shaft drive, and a universal joint is attached to the squared driving end.

The planetary gearing shown at Fig. 252 is that used in Ford automobiles and its operation is similar to the forms previously described. In this mechanism, however, the master clutch which provides the direct drive is a multiple-disk form composed of steel disks, which are kept in permanent contact and proper driving relation by means of a heavy coiled spring. The low and reverse speeds are obtained in the conventional manner by tightening the external contracting clutch bands, which are shown between the gearing and disk clutch.

Planetary gearing has been very successful when properly designed and installed, and its chief disadvantage is that it is very difficult to provide more than two forward speeds and one reverse. For this reason it can only be adapted to light cars which have a surplus of power in the engine, or to heavy trucks where it is not so essential that a large number of speed ratios be provided as in touring cars. Such gearing is not efficient on low and reverse speeds as considerable power is absorbed in friction, but when on the high speed or direct drive it is superior to any other form of change-speed gearing because the entire assembly is locked to the crank shaft, no gears are turning idly, and the weight of the gearing serves merely as an additional fly-wheel member. Considerable trouble was experienced with the early forms because it was difficult to keep oil in the case, but in modern forms special care has been taken in housing the reduction gears so these are constantly oiled, and both wear and noise, which were formerly detrimental to the adoption of this form of gearing and which militated largely against its general use, have been eliminated.

Individual Clutch Transmission.—A form of gearset which combines the good features of the planetary type in that the driving gears are always in mesh and which can be provided with any desired number of speed ratios is known as the individual clutch type. In gearsets of this form one set of gears is carried by the countershaft and is fixed thereto while another set of gears, with which these members mesh, revolve idly on the main driving shaft.

A transmission of this type which has been applied successfully in motor-truck design is shown at Fig. 253. In this the power is delivered to a main shaft, which is supported on ball bearings and which carries a bevel pinion engaged with a bevel gear for driving the wheels at the rear end. The gears mounted on the main shaft are normally free to revolve independently from the shaft unless they are clutched to it by sliding positive jaw clutch members driven

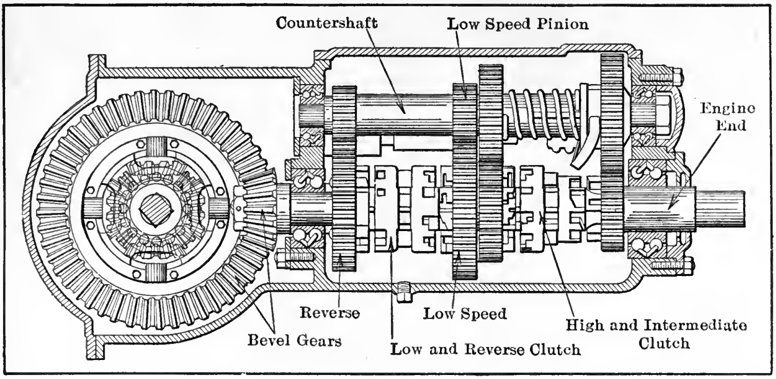


Fig. 253.—Part Sectional View of Cotta Individual Clutch Transmission Designed for Heavy Motor Truck.

by the main shaft. Any desired speed ratio may be selected by engaging the gear desired by means of the clutch carried at its side, thus causing it to turn with the shaft.

When the clutches are placed as shown in illustration, the gears are neutral and the driving shaft turns without producing movement of the bevel driving gears. If it is desired to engage the low speed the low and reverse clutch member is moved toward the front end of the gearset until it clutches the low-speed gear to the main shaft. The power of the engine is then applied to the countershaft through the constant mesh gears at the extreme front end of the gearset and as the main shaft is made in two pieces, the end of one member telescoping into the portion that carries the driving connection to the engine, the drive is back from the countershaft low-speed pinion to the big gear which has been clutched to the main shaft and which causes it to turn slower than the driving member attached to the engine.

To obtain a reverse ratio the low and reverse clutch is moved to the back end of the transmission and the reverse gear is locked to the main shaft. To obtain direct forward drive the high and intermediate clutch member is pushed forward until it engages the teeth on the side of the constant mesh gear. This operation locks both portions of the main shaft together and causes that part to which the bevel driving pinion is secured to turn at the same speed of rotation as the driving end which is joined to the engine. The clutches are arranged in such a manner that only one can be used at a time and in addition to the positive clutches carried in the gear case some form of master clutch, which is invariably of the friction type, must be provided between the power plant and the gearset.

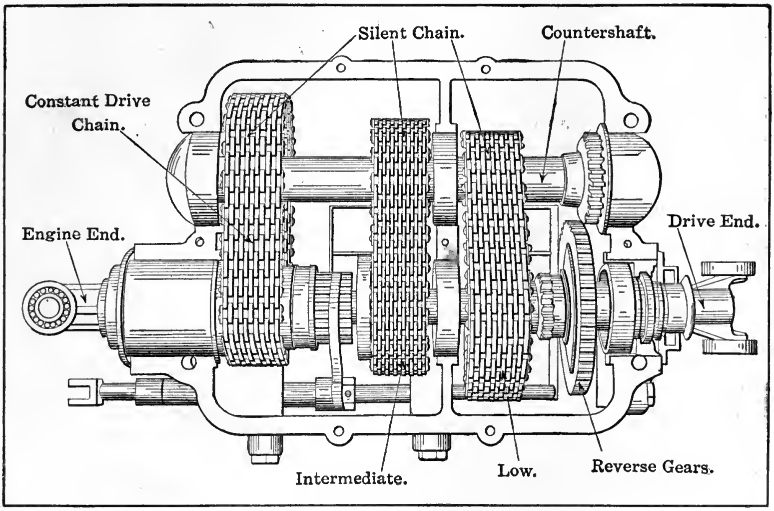


Fig. 254.—Individual Clutch Transmission Using Silent Chain Connection Between Main and Countershafts for Forward Speeds and Sliding Spur Gears for Reverse Action.

There is a growing tendency to apply the silent chain to positive individual clutch types of transmissions instead of utilizing direct gear connection. The application of silent chains to a gear box is shown at Fig. 254, and the sectional view which is shown at Fig. 255 makes the method of operation clear. The advantage of the silent chain when used in gear boxes of this character is that it provides a more silent drive than direct gear connection would. This is very valuable in the case of heavy, low-powered cars such as omnibuses and commercial vehicles, where the gearing is frequently used and where the vehicles are operated for the most part under traffic conditions which make noisy operation undesirable. The method of operation when silent chains are used is exactly the same as though the drive was by spur gearing.

Referring to the sectional view of the gear box given at Fig. 255, it will be seen that the power from the motor is delivered to a drive

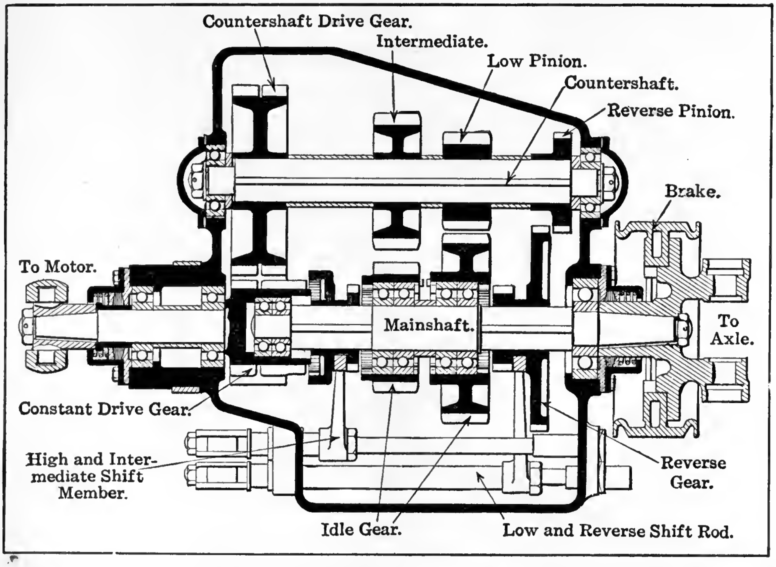


Fig. 255.—Sectional View of Individual Clutch Gearset with Silent Chains Removed to Show Arrangement of Gearing.

sprocket in the interior of which the end of the main shaft telescopes and which is supported by suitable ball bearings. The countershaft mounted above the main shaft carries four gears, three of which are adapted to use silent chains, while the smallest member is a clash gear of the conventional pattern, employed only to obtain reverse speed. It will be observed that two gear members are carried by ball bearings at the center of the main shaft in such a way that they revolve independently of that member unless they are clutched to it by the positive clutches keyed to the shaft.

To obtain the reverse drive the large reverse gear is moved back in such a way that it engages the reverse pinion on the countershaft. The drive in this case is from the motor to the constant drive gear, forming part of the main shaft which turns the countershaft drive gear by means of a silent chain which is not shown in this view but which can be very clearly seen at Fig. 254. The countershaft is turning in the same direction as the motor and the spur gears used at the back end of the gearset are employed to reverse the motion. When the low speed is desired the low and reverse shift member is moved in such a manner that the idle gear is clutched to the shaft. When this condition obtains the drive is from the motor through the constant drive gears and from the countershaft by the low-speed pinion and the big gear which has been clutched to the main shaft and which serves to drive the universal joint connected to the bevel gearing in the rear axle.

A movement of the high or intermediate shift member will give either of these speeds desired. The intermediate speed is obtained in exactly the same manner as the low speed except that the gear ratio is such that a higher ratio of drive is provided, while the high speed or direct drive is obtained by locking the two sections of the main shaft together.

How Sliding Gearsets Operate.—The majority of change-speed gearsets which have been generally fitted to automobile service are forms of sliding gear arrangements and may be divided into two main classes. In progressive sliding gearsets but one member is employed for all speeds and this is shifted along from one extreme position to the other. In the selective system it is possible to go into any one of the speeds or gear ratios desired without passing into other speeds and with but a limited movement of the shifting members.

The sliding gear system was one of the first to receive general application in early forms of motor vehicles and in its primitive condition it was but a modification of the back gearing used on certain classes of machine tools, such as lathes, drill presses, etc. One of the advantages of this type when compared to other gear transmissions is that it is possible to provide a greater number of speed changes and that there is a higher driving efficiency when on the lower ratios because but two pairs of gears are in mesh.

An example of a progressive sliding gear transmission is depicted at Fig. 256, this providing three forward speed ratios and one re-

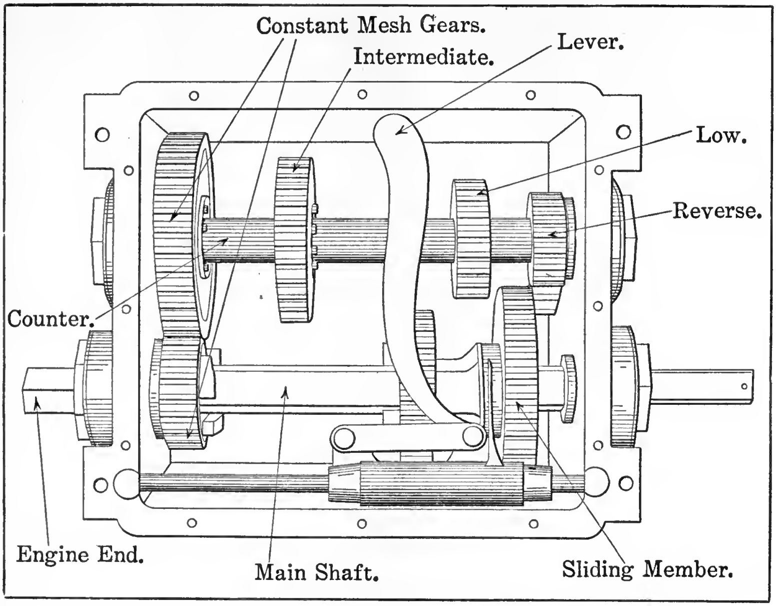


Fig. 256.—Arrangement of Gears in Progressive Sliding Gearset.

verse. The various speed ratios are secured by moving the sliding member which is composed of two gears along the main shaft so that it engages successively the gears on the countershaft. When the sliding member is in the position shown, no gears are engaged and no power can be transmitted through the gearset. If the sliding member is moved toward the right so that it engages the small pinion under the reverse gear on the countershaft a reverse drive would be obtained. If the sliding member is shifted toward the left until the large gear member engages with the low-speed gear on the countershaft the lowest forward drive ratio is obtained.

Continued movement of the sliding member toward the left will cause the small gear to engage with the intermediate pinion and produce a ratio of drive that will not be as fast as the direct con-

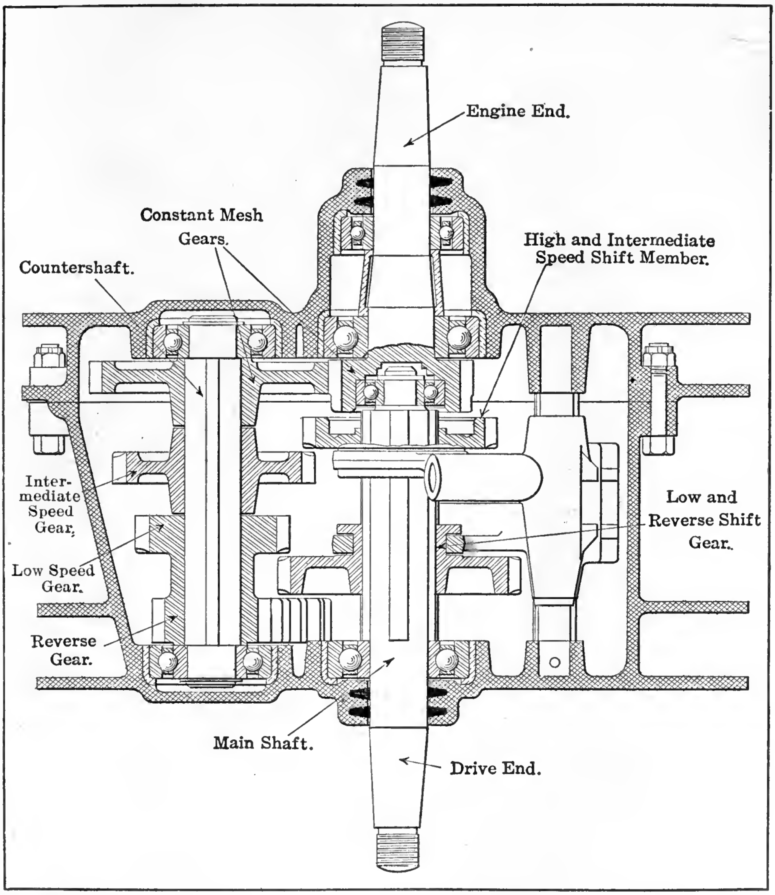


Fig. 257.—Showing Application of Two Shifting Members on Main Shaft of Selective Sliding Gear Speed-Changing Mechanism.

nection but which is faster than the slow-speed ratio. When the sliding member is moved to the extreme left it serves to lock the two portions of the main shaft together and a direct drive is obtained. The power from the engine is first delivered to the constant mesh gear which normally drives the countershaft and which revolves around the main portion of the main shaft which telescopes into its interior.

If the design of this gearset be compared to that outlined at Fig. 257, it will be evident that in the latter two shifting members are employed which have a smaller degree of movement than the single member of the progressive type. The reason that the selective system is generally preferred may be easily understood by referring to the comparison between the forms as shown at Fig. 258. In the progressive sliding gearset which is shown at A, the shifting member

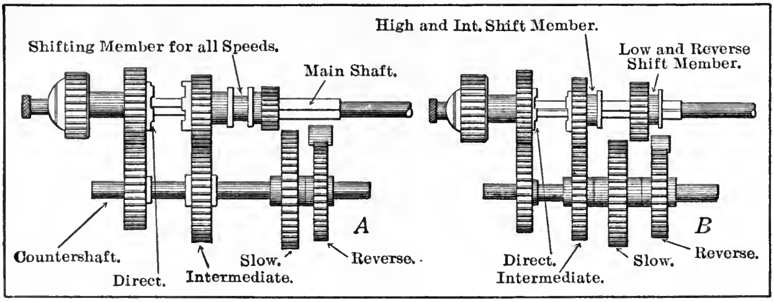


Fig. 258.—Comparing Progressive and Selective Gearset Action to Demonstrate Advantages of the Latter Form.

is shown engaged with the intermediate gear on the countershaft. If it is desired to pass into the reverse from this position the slow speed must be engaged before the reverse gear can be reached. The hand lever used to shift the gearing is moved back with one continuous movement. For instance, if the gearing be in the reverse position and it is desired to engage the direct drive it will be necessary to pass the one shifting member to the low speed, past the intermediate and from thence into the direct drive position.

With the selective gearset which is depicted at Fig. 258, B, the plurality of shifting members provided makes it possible to go into any speed directly without passing through the others. For instance, the high and intermediate shift member is shown in the position at which the intermediate speed ratio is obtained. If it is desired to engage the high speed this member may be pushed directly into position so that the main shaft and the constant drive gear are locked together. If it is desired to go into reverse a simple movement of the operating or shifting member, which is guided by an H slot gated segment, will disengage the high speed and throw the other shift member into position by one simple movement.

One of the advantages of this method is that it is much easier to engage the gears and that the liability of injuring the gear teeth by injudicious shifting is not as great as in the progressive type. Another advantage of the selective system is that it permits a more compact construction and makes possible the use of shorter shafts which are stiffer than longer ones because the distance between points of support is not so great. Not only is the operation much easier but it is possible to obtain the varying speed ratios much more quickly than with the progressive system.

The usual number of gear ratios provided is three forward speeds and one reverse motion. On some of the heavier touring cars four forward speeds are provided and when this is done engineers differ as to whether the direct drive should be on the third or fourth ratio. When the direct drive is on the third ratio the fourth speed is obtained by gearing up and the driving shaft revolves faster than the main shaft of the engine. When the fourth speed is a direct drive the crank shaft and the driving shaft turn at the same speed. Those who favor the former method contend that as most of the regular driving is done at a medium rather than at an extreme high speed the direct drive on the third is preferable to a direct drive on the highest ratio. The geared-up fourth speed can be used only when conditions are exceptionally favorable to high speed. If the highest speed was obtained by a direct drive the natural tendency of the motorist would be to use this most, but there would be many conditions where the ratio would be too high and one of the lower gears would have to be used. If the direct drive was obtained in the third ratio this would be employed the greater part of the time, and as there would be less wear on the gearing with the direct drive engaged it would be preferable to use this as much as possible.

The question of gear ratio to use depends entirely upon local conditions and before determining the ratios of the gearing in the speed-changing mechanisms it is imperative that a definite relation be established between the speed of the driving shaft and the road wheels. When heavy pleasure cars use engines of moderate power the gear reduction is usually three and one half or four to one, this meaning that when the gearing is in the direct drive the engine crank shaft will turn three and a half or four times to one revolution of the driving wheels. On cars where the margin of power is large and where high speeds are desired the ratio may be but two and one half to one. If the car is geared too low, the engine must make a very high number of revolutions when on the highest speeds and use much more fuel than necessary. On the other hand, if the driving ratio is too high it will be necessary to change gears frequently because even moderate grades will make it imperative to use a lower ratio than that afforded by the direct drive.

The body fitted to the car has a material bearing upon the gear ratios provided. The driving speed that would be entirely practical on a chassis fitted with a roadster body would be much too high if a limousine or coupé body was fitted to the same chassis. If the car is to be operated in regions where the conditions are not favorable, such as hilly sections, or where the highways are poorly developed, a much lower final drive ratio must be provided than where the roads are good and conditions favorable to higher speeds. The speed ratios when the low gears are engaged will vary from ten to one to such extremes as twenty-five to one. The intermediate speed usually varies from five to one to ten to one, and a third ratio in a four-speed gearset may vary from three to one to six to one, and in some gearsets it may have a value of seven or eight to one. If the fourth speed is obtained by gearing up one may get a ratio of drive as high as two to one, though when the direct drive is on the fourth speed it is seldom higher than three to one.

Most of the sliding gearsets have at least one of the speeds a direct drive, but some forms have been devised where the power is transmitted through gears at all ratios. A gearset of this type, which has been used in an English omnibus, is outlined at Fig. 259. This operates on the selective principle, but the drive at all speeds is through gears. Two shifting members are mounted on the main shaft. One of these carries two small gears, the other has two larger members. When the highest speed ratio is desired, the largest gear on the main shaft is engaged with the smallest member on the countershaft and as these have an equal number of teeth the shafts will turn at the same speed. When the smallest member on the main shaft is engaged with the largest gear the slowest ratio is obtained. This method of gearset construction is seldom followed at the present time be-

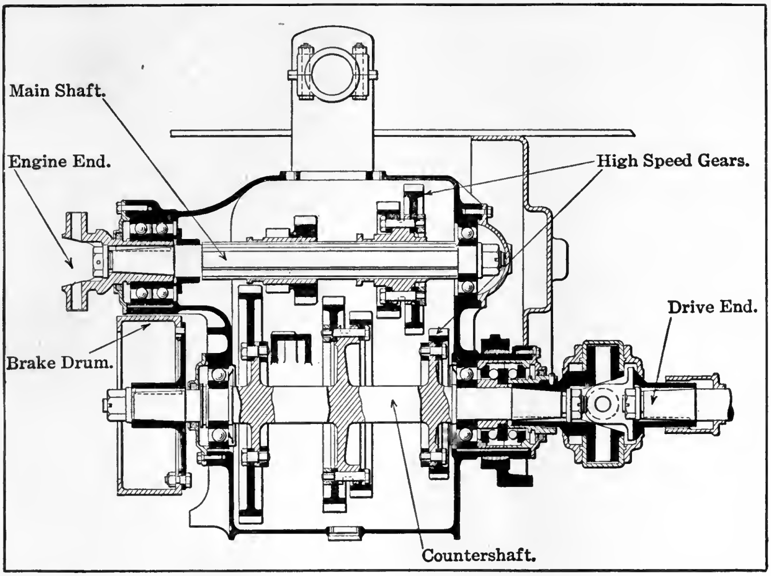


Fig. 259.—Three-Speed Selective Gearset in which All Speeds are Obtained by Gears, No Direct Lock Being Provided for High Speed.

cause of the constant grinding of the driving gears at all speeds, and a certain amount of noise will result no matter how carefully the gears are fitted. With those forms of gearsets in which the highest ratio is obtained by locking the two parts of the main shaft together there are no gears transmitting power except those in the rear axle, and the operation is much more silent. The gearset is more efficient because the power loss is reduced to that of but one set of driving gears, and as no gears in the gearset are under driving loads there is no grinding or noise when on the direct drive.

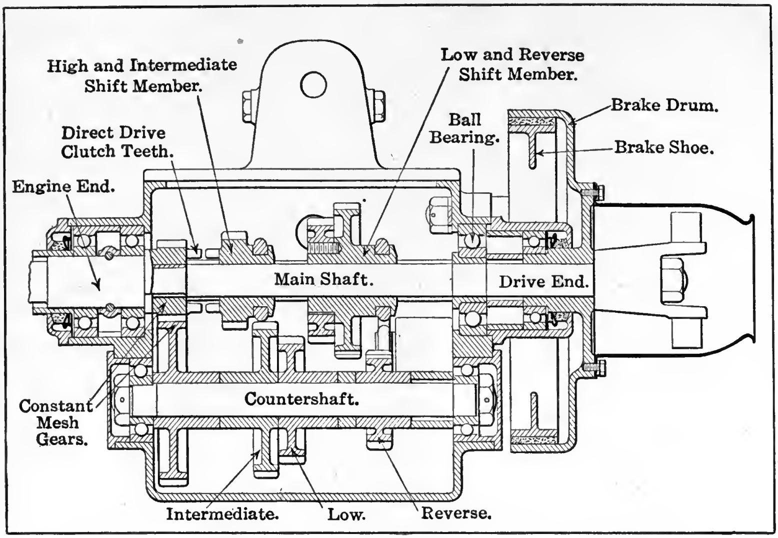


Fig. 260.—Arrangement of Gears and Shafts in Typical English Three-Speed Selective Gear Box.

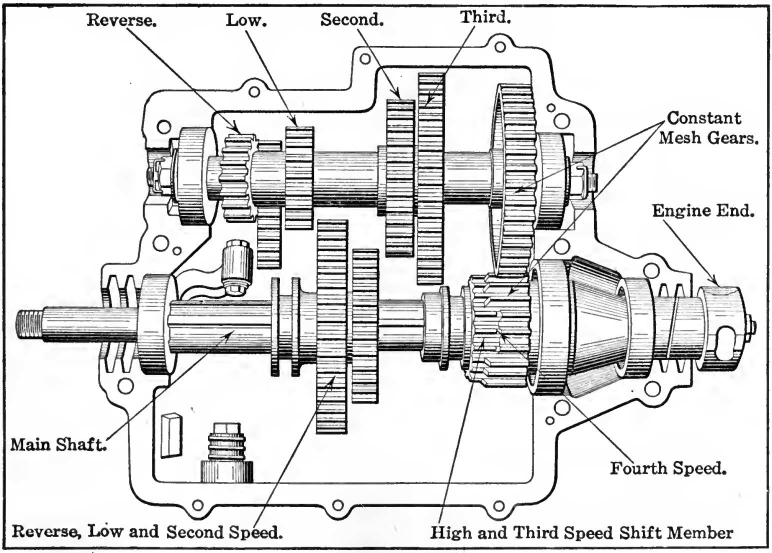


Fig. 261.—White Four-Speed Gearset Has Direct Drive on Highest Ratio.

A typical sliding gearset of the three-speed selective type is shown in section at Fig. 260, and at Fig. 261 a four-speed gearset in which direct drive is obtained on the fourth speed is outlined. In the former, two shifting members are mounted on the main shaft, one of these giving the high and intermediate ratios, while the other is employed for low and reverse speed. But two shifting members are utilized on the main shaft of the form shown at Fig. 261. One of these acts progressively to give the reverse, low, and second-speed ratios, while the other gives the third and fourth speeds.

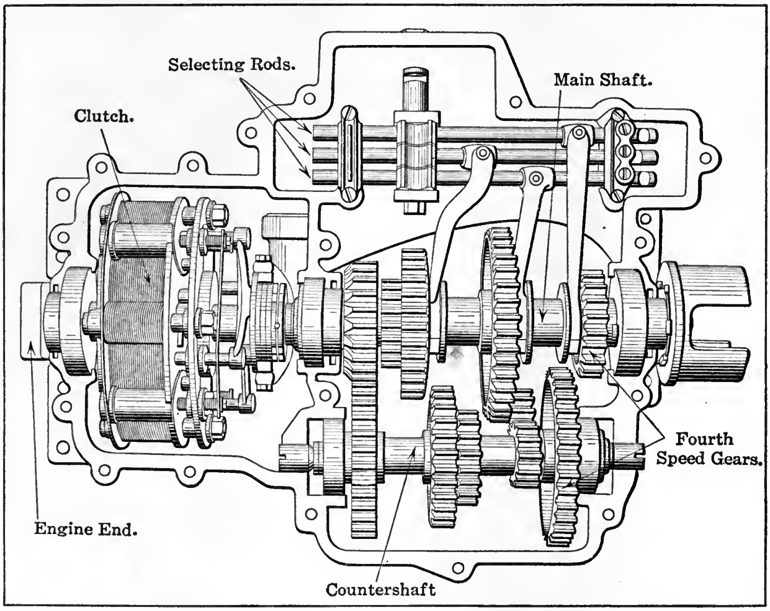


Fig. 262.—Winton Four-Speed Gearset Provides Direct Drive on Third Speed and Gears Up for Highest on Fourth-Speed Ratio.

A four-speed gearset in which three shifting members are used and in which a geared-up drive is obtained on the fourth speed and a direct connection on third is shown at Fig. 262. In this the clutch is mounted at the forward end of the gearset in a case of its own and is a multiple-disk type. The member shifted by the center selective rod gives the second and third speeds, while that moved by

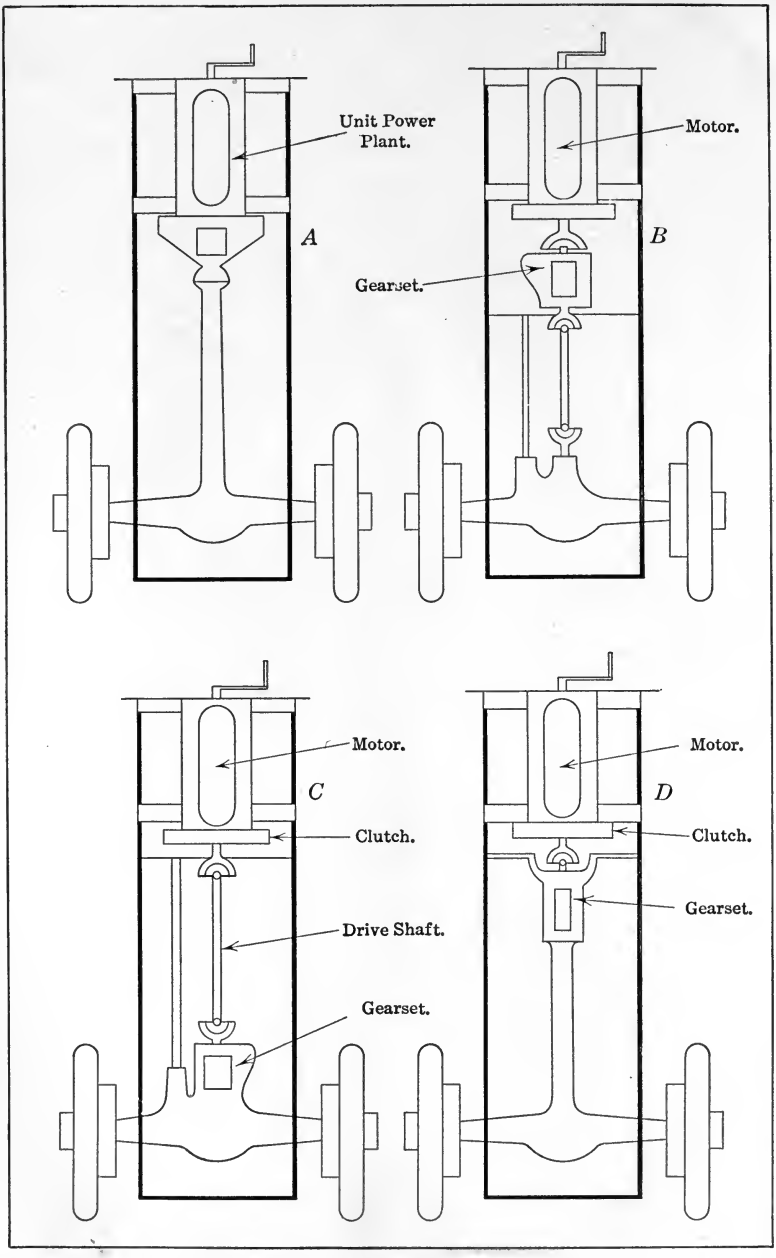


Fig. **263**.—Conventional Methods of Installing Gearsets in Chassis. A—Combined with Engine to Form Unit Power Plant. B—Fitted as an Individual Unit Back of Engine. C—Combined with Rear Axle. D—Mounted at Front End of Driving Shaft Housing.

the inner rod gives the reverse and first speed. The geared-up drive or fourth speed is obtained by shifting the outer selective rod and bringing the smallest gear on the main shaft in mesh with the largest gear on the countershaft.

An important factor in gearset design is the method of locating it in the frame. The various systems of gearset mounting in common use are shown at Fig. 263. In that depicted at A the clutch and gearset form a unit with the power plant. The advantage of

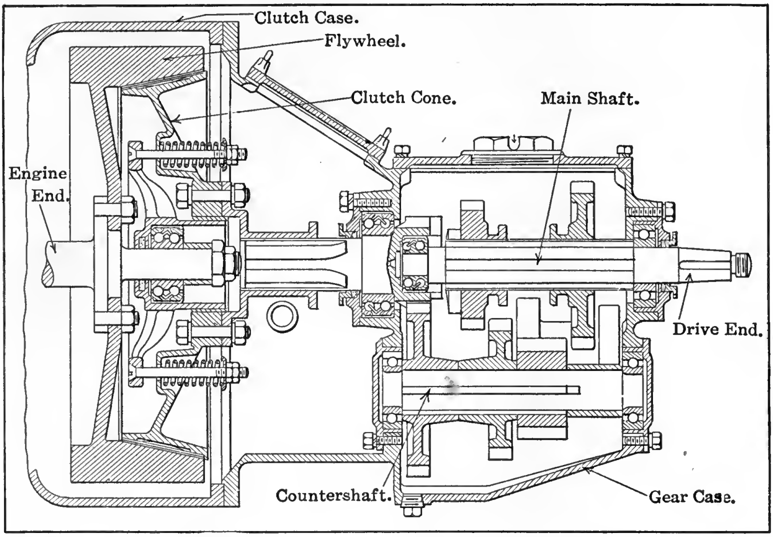


Fig. 264.—Clutch and Gearset Portion of Unit Power Plant Showing Positive Alignment Between Clutch and Gearset Main Shaft.

this method of mounting is that it makes a very compact power-generating and speed-changing unit and there will be no liability of lost alignment between the engine and gearset. At B the gearset is a separate member installed back of the motor just under the front floor boards, and when mounted in this manner it may be attached directly to the main frame side members or to a subframe formed by cross members which have been provided for the purpose. In the design outlined at C the gearset is a unit with the rear axle, and the same argument in favor of mounting applies as when it forms part of the unit power plant except that in this case there is no possibility of lost alignment between the gearset and the driving gears. The method of installing which is fourth in popularity is shown at D. In this the gearset is carried at the front end of the driving shaft housing and is usually attached to the frame in such a manner that it will assist in taking braking and driving torque.

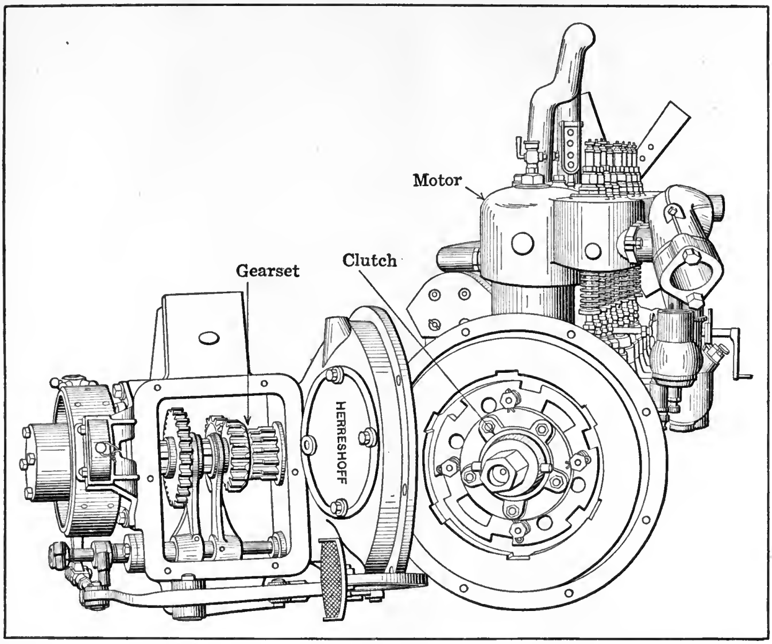


Fig. 265.—Herreshoff Unit Power Plant Partially Dismantled to Show Clutch and Gearset Construction.

The methods of combining the gearset with the clutch case and power plant are shown at Figs. 264 and 265. In the former construction the engine is shown detached for convenience, but the clutch case is a continuation of the engine bed. At Fig. 265 the gearset is shown detached from the power plant in order to demonstrate that the clutch may be easily reached when desired. When the parts shown are assembled to form a unit the flange at the front end of the gearset case is attached to that at the back end of the engine bed by means of bolts and the two then form a cover for the fly wheel and multiple-disk clutch which it carries.

When side-chain drive is provided, as is often the case in motor trucks, the gearset sometimes forms part of the countershaft assembly. One of these designs is shown at Fig. 266, this illustrating the general arrangement of parts, while more specific details of construction are outlined at Fig. 267. The construction is exactly the same as though the countershaft assembly was employed as a live rear axle with shaft drive. The only difference is that the ends of the live axle shaft are provided with driving sprockets instead of

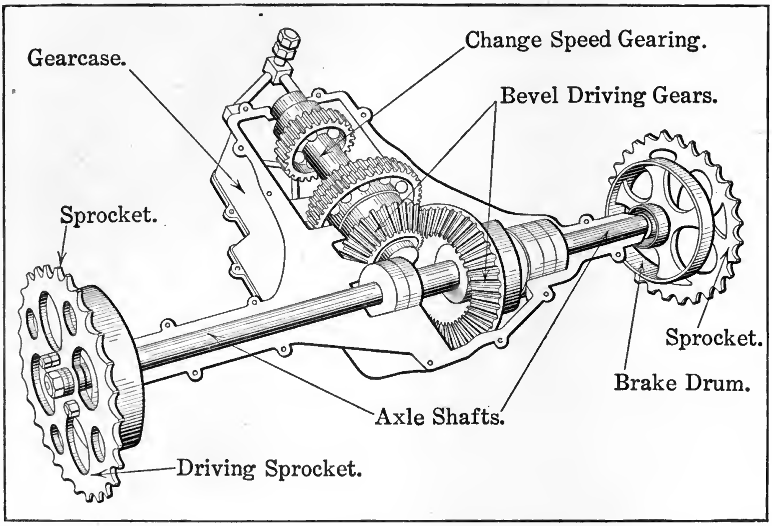


Fig. 266.—Change-Speed Gearing Combined with Countershaft for Side-Chain Drive.

wheel hubs. At Fig. 267 the arrangement of the three-speed selective gearset and the manner in which the bevel-driving gears mesh is clearly shown. The small driving pinion is attached directly to the main shaft extension and there is but little possibility of losing alignment under load. The shafts of the transmission gear are mounted on ball bearings while the differential and axles are mounted on

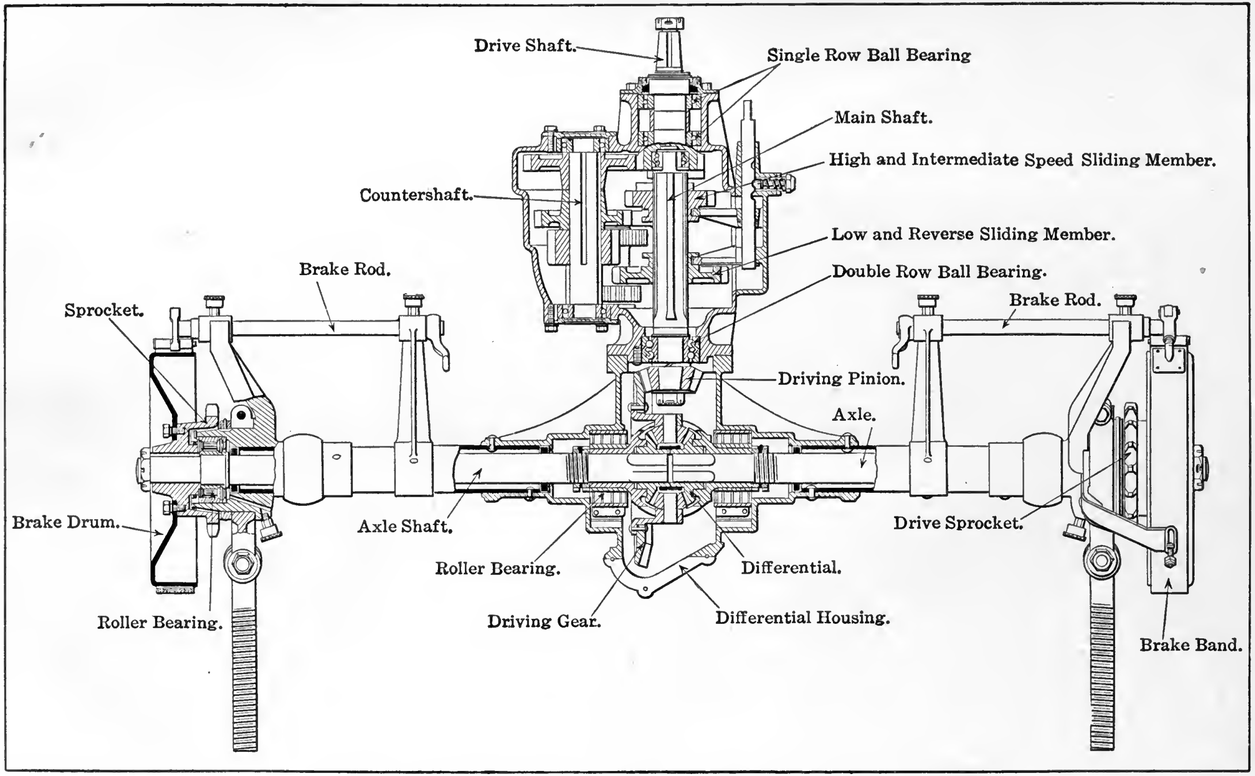


Fig. 267.—Countershaft and Three-Speed Selective Sliding Gearset Mounted as a Unit Insures Positive Alignment of Speed-Changing and Power-Transmitting Elements.

roller bearings. The drive sprockets carry pressed steel brake drums to which large external constricting brake bands are applied. These serve as "running" or service brakes to arrest vehicle motion through the medium of the driving chains which connect the small sprockets with the larger members on the wheels.

An unconventional form of rear axle and gearset combination is shown at Fig. 268, while the conventional arrangement is depicted at

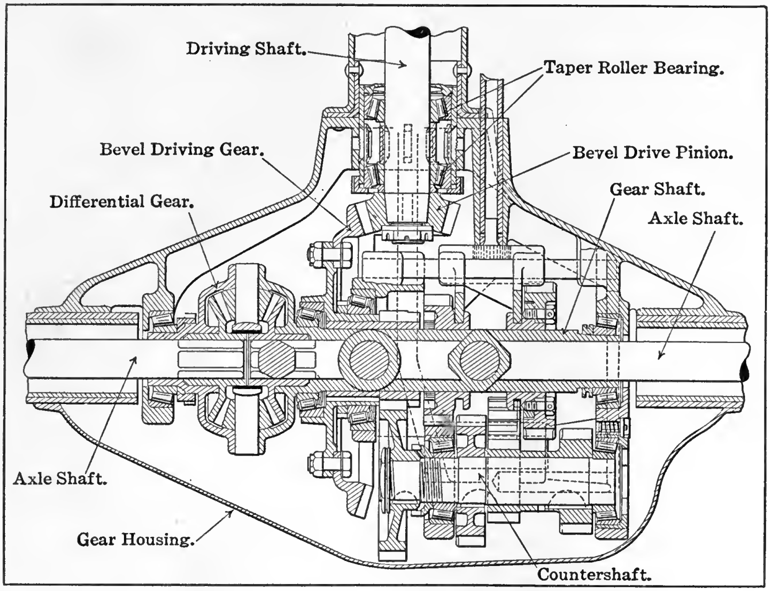


Fig. 268.—Unconventional Arrangement of Three-Speed Selective Sliding Gear-set in Combination with Rear Axle to Secure More Compact Construction by Housing Change Speed and Driving Gear in Common Use.

Fig. 269. In the former the main shaft of the gearset is in the form of a quill or tube which surrounds one of the axle shafts and the countershaft is a separate member carried directly in back of the main shaft. When on the direct drive the high-speed shift member is moved toward the left and locks the differential gear case firmly to the quill, which acts as the main shaft. When the parts are locked together in this manner a direct drive is obtained. The lower speed

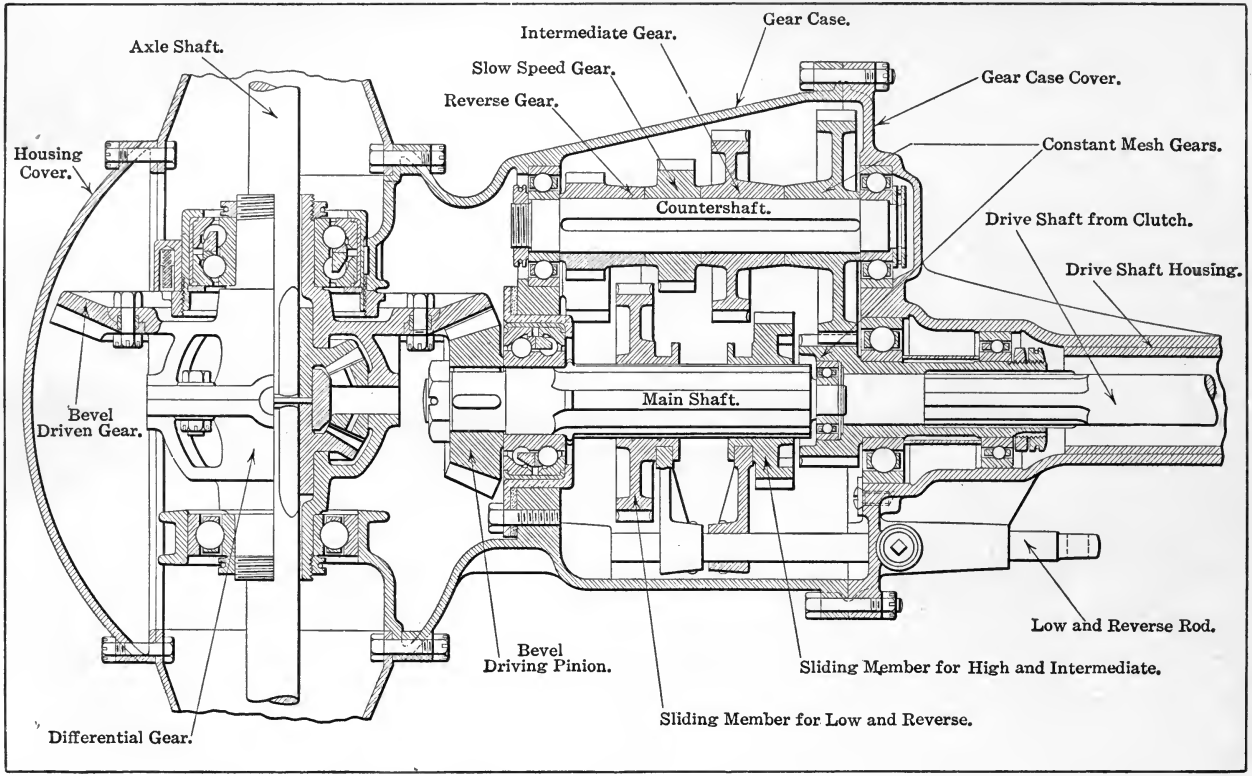


Fig. 269.—Usual Arrangement of Change Speed and Driving Gearing at Differential Housing of Live Rear Axle or Countershaft.

ratios are obtained in the same manner as in any other selective transmission, the gears on the main shaft being moved to engage the corresponding members on the countershaft. The contention is made that this method of design makes for a more compact assembly as all parts are housed in one casing member.

Most engineers who favor combining the rear axle and the transmission use the construction outlined at Fig. 269. In this all parts are so clearly shown that the method of application should be sufficiently clear without lengthy description. The change-speed gearing is a conventional three-speed and reverse selective sliding gear type and the drive to the rear axle is by the usual bevel-gear connection. The various systems of driving and methods of manipulating the speed-change levers will be considered more fully in proper sequence.

CHAPTER IX

The Chassis and Its Components—Frame Design and Construction—Typical Methods of Spring Suspension Outlined—Function of Steering Gears—Steering Gear Forms Defined—Front Axle Types—Rear Axle and Driving Means—Power Transmission by Bevel and Worm Gearing—Conventional Braking Systems—Application of Front Wheel Brakes.

The average motor-car chassis is composed of a number of parts distinct from the power plant and transmission groups. The important components are the axles, the steering system, the method of power transmission to the wheels, the design of the frame, and the spring suspension means. The frame forms a connecting link between the motive power and the parts which serve to support the body and machinery. Formerly frames were made in many different styles and a number of different materials were utilized in their construction. At the present time the practice has crystallized to a point where certain construction has been definitely accepted as the best and this is generally followed in practically all forms of motor cars.

Frame Design and Construction.—The usual arrangement of the components of typical chassis forms is outlined at Fig. 270. The power plant and its accessory groups as well as the change-speed gearing have been previously described, and the chassis forms outlined are presented to show the two distinct systems of chassis construction generally followed. The arrangement of parts depicted has become accepted as best practice and practically all motor cars are about the same in general design. The arrangement of the chassis shown at A is the conventional one, and in this the frame which carries the operating parts is mounted above the axle. In the form shown at B an underslung frame construction is used. In this case the springs are coupled to the axles but the frame members are suspended from the springs instead of being placed above them as shown at A.

The advantages claimed for the underslung construction are that it is more stable because the weight is carried nearer the ground and the car is more easy riding and will sway less at high speeds than those types where the frame is carried above the axle. The advantage of bringing the center of gravity close to the ground is clearly illustrated at Fig. 271. At A the center of gravity of a heavy limousine car which has an underslung frame is at a point just above the axle,

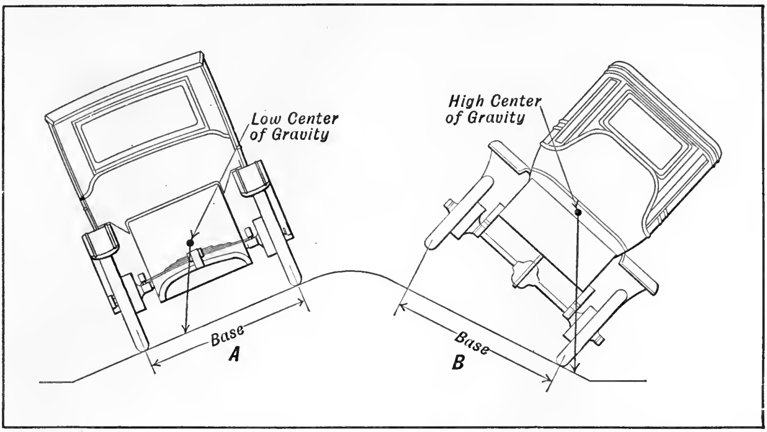


Fig. 271.—Advantage of Low Weight Placing and Carrying Center of Gravity Near the Ground. A—Low Center of Gravity Makes for Stability. B—High Center of Gravity Unsafe.

and if the car tilts over a marked degree, a line drawn from the center of gravity will fall within the area of the base of support as represented by the rectangle, the corners of which are at the contact points of the wheels and the ground. The center of gravity of any body is the theoretical point around which the weight may be said to be evenly distributed, and whenever a line drawn from the center of gravity falls within the base line of any body or mass it is in stable equilibrium.

In the case outlined at B the center of gravity is carried higher because the frame is mounted above the axle and conditions may obtain where the line drawn from the center of gravity will fall outside of the base line and the car tip over. While the conditions shown are somewhat exaggerated they will serve to make the comparison clear and will enable the nontechnical reader to understand the advantage of carrying the weight of the machinery as near the ground as possible to secure steadiness at high speeds.

The factor of carrying the weight low is much more important in the case of cars which are to be equipped with large closed bodies of the limousine type. It must not be inferred that it is not possible to carry the weight low with the form of frame construction defined at Fig. 270, A, as in the case illustrated the machine weight is carried practically as near to the ground as it is when the underslung frame shown at B is employed. The difference in center of gravity of the whole machine is evident only when the body is fitted and it will be carried considerably lower with the underslung frame than in the one where the frame members are mounted above the axles.

Materials Employed in Frame Construction.—The first motor cars were based somewhat on experience obtained in bicycle construction and had frames made of steel tubing. This material was not as suitable for motor-car frames as it had been for the lighter two-wheeled vehicles because the multiplicity of brazed joints necessary made the frame quite a costly proposition. Then again the round section of the tubing did not offer as easy means of attaching the engine and transmission units as do those frames which are composed of members having a rectangular section. Tubing is used only in subframe work, at the present time notably in the Flanders light four-cylinder car and some of the Lozier models.

Following the use of the tubing, automobile builders used angle iron and other structural shapes available on the open market. Other makers used wooden frame members, but at the present time one rarely finds either structural iron or wood used in pleasure cars, though both of these materials have been applied to some extent in motor-truck construction. Some makers, notably the Franklin Company, employ frames which are made of laminations of specially seasoned and strong wood. The majority of manufacturers, however, favor the use of pressed steel forms which are not only light and strong but which have a degree of flexibility which is very desirable and which is not easily obtained with the various structural shapes in iron.

Frames may be divided into five main classes, as follows: Those in which wood only is used, forms utilizing pressed steel construction, types employing steel tubes, frames built up of iron structural shapes, and combination frames where two or more different methods of construction may be combined. For instance, it is possible to reënforce a wooden frame side member with a strip of steel or iron, or at the other hand some makers sometimes fill the channel of a pressed steel frame with wood to strengthen it. Each of these main divisions might be again divided. For instance, wood frames may be made of a solid strip or beam or may be composed of vertical or horizontal laminations. Pressed steel may be made into channels, angles, or modifications of these, while frames composed of tubing may be square, rectangular, or round section. The various structural shapes may be utilized in the form of plate, angles, T rail sections, and I beams.

A typical pressed steel frame is shown at Fig. 272 and this is the type which is very generally employed. The frame-side members are

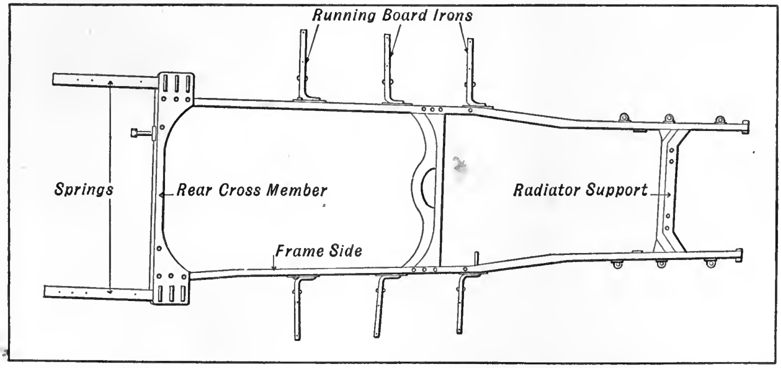


Fig. 272.—Conventional Form of Pressed Steel Automobile Frame with Cambered Side Members.

two pressed steel forms cambered at the front ends and joined together by a series of three cross braces. The front one serves as a radiator support, that in the center provides anchorage for the torque tube of the axle, while the rear cross member projects on either side of the frame and provides a point of anchorage for the rear supporting springs. The object of cambering the frame members in front is to provide a greater angle of operation for the front wheels and to permit turning on curves of smaller radius than would be possible if the frame members were straight and movement of the wheels limited thereby.

In some frame constructions where semi-elliptic springs are used at the rear end as well as the front of the car, the frame is sometimes raised at a point directly over the axle, as shown at Fig. 273, A. Often a double drop is provided in the frame side, as shown at Fig. 273, B. In this construction the frame side is straight to a point

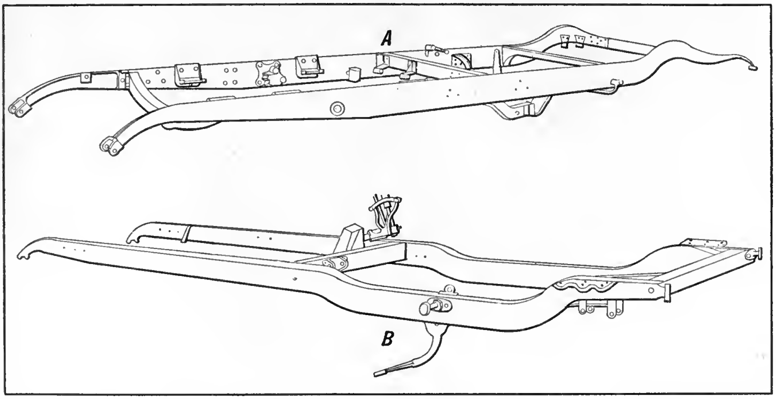


Fig. 273.—Frame Forms Having Raised Side Members. A—Frame Side Raised Over Axle. B—Framework with Drop Side Member.

about half the length of the chassis, then it drops and when it reaches the axle it raises again to allow for movement of the axle. The object of dropping the frame is to provide a slightly lower floor board placing than would be possible if the body was carried at one level. The rear upsweep, by raising the back end of the frame, enables the axle to be carried in a position that will permit a nearly straight line drive. It will also bring the running board of the car closer to the ground, which makes the body more accessible, and it lowers the center of gravity as well. At the same time sufficient space is provided between the raised rear end and the axle to permit of using springs which will be adequate to support the weight of the mechanism and body and yet permit these to have a considerable radius of movement and make for much easier riding.

By bringing the lowest level at a point between the front and rear it is possible to carry the body low and at the same time support the engine and transmission at a sufficient height above the ground to insure ample clearance between the bottom of the motor and the surface of the roadway. The advantage of the pressed steel frame over the other forms is that it is a very easy type to make and very cheap after the forming dies have been made. It lends itself readily to designs where it would not be possible to use the wood frame because of the serious diminution of strength if wood is bent in any way that will distort the grain.

Suspension of Motor Vehicles.—One of the most important problems in connection with chassis designing is that of the supporting members which join the frame to the axles and which are depended upon to absorb much of the shock and jar incidental to motor-car operation. The importance of the springs and the part they play in promoting the comfort of the passengers, the durability of the machinery, and economical application of power are but little appreciated by the majority of motorists. One point that has made it difficult for the automobile designer to evolve spring types which were entirely satisfactory was the paucity of data regarding spring action of high-speed vehicles. The forms of springs that were used on wagons and carriages were studied, but when these were applied to motor cars which had much greater speed than the simpler vehicles the problem assumed a new aspect. While the horse-drawn vehicle operates on rough roads the speeds are comparatively low, and the roughness of the roads is not such an important factor as it is in the design of automobile springs. Railway cars were studied in the hope of finding a solution. Here the conditions are reversed, and while they operate at high speeds they run on comparatively level-steel rails and the conditions of operation make the problem of spring suspension one that is not difficult.

One point greatly in favor of the motor car is that for the most part these are mounted on pneumatic- or air-filled tires and these have valuable cushioning properties in themselves and are of material value in solving the problem of spring suspension. It is very difficult to combine both strength and resiliency in springs, as if these are made light and flexible they are not likely to be strong. A vehicle that might be very easy riding on good roads would have too much spring movement if the springs were lacking in strength when operated on rougher road beds. At the other hand, if springs are made stiff to take care of severe conditions they will be hard acting when used on smooth roads.

Another factor which makes it difficult to select the proper springs is the variation in weight carried. When an engineer designs a five-passenger touring car he must provide springs of adequate strength to take care of the car when it carries its full complement. If but two passengers are carried the car will be stiffer riding than when the weight of five persons must be supported.

An added point that makes it difficult to select springs for automobile suspension except by experiment is that the propelling force forms part of the conveyance and power must be transmitted from the source mounted on the frame to the wheels resting on the ground. As the frame is suspended on more or less flexible members and moves in various directions, the degree of movement must be limited so there will be no excessive strain imposed on the transmission mechanism. Ease of riding is largely determined by the radius of movement or upward throw of the body, and the object with any kind of spring suspension is to reduce the up and down movement to as low a point as possible without actually retarding the vibrations. Rapid vibration of the springs will cause discomfort and will affect to a considerable degree various parts of the chassis which connect the frame to the axle, such as radius rods, steering connections, torque members, and driving means.

Of the various forms of springs it is possible to use the laminated leaf spring is that which has been generally applied on automobiles just as its use has become universal on horse-drawn conveyances. The great value of the laminated leaf spring is that its capacity can be varied by changing the number of plates or leaves used and almost any desired degree of resiliency can be obtained by varying the thickness, grade of material, and width of the plates of which the spring is composed.

Design of Leaf Springs.—The leaf springs used for the suspension of road vehicles consist of several layers of steel plates so shaped that when laid together they form superimposed arcs of as many circles as there are leaves. The spring effect is obtained by the elasticity of the metal used which is increased in value by a process of heat treatment known as tempering. The leaves are usually graduated in thickness, being thicker at the center and tapering from the center to the ends.

The reason for following a common line or arc when a spring is composed of more than one leaf is that as all of the leaves are deflected at once by the load and as the tendency is to straighten out the curved member, they should slide upon one another when altering their shape in such a manner that they will always be in contact with the neighboring leaf at all points. If the curvature of the leaves differed appreciably the tendency of the plates under load would be to straighten out and separate and the load would only be carried on those members which were in contact at all points. This would be undesirable because it would cause a loss of spring action and would also result in frequent breakage.

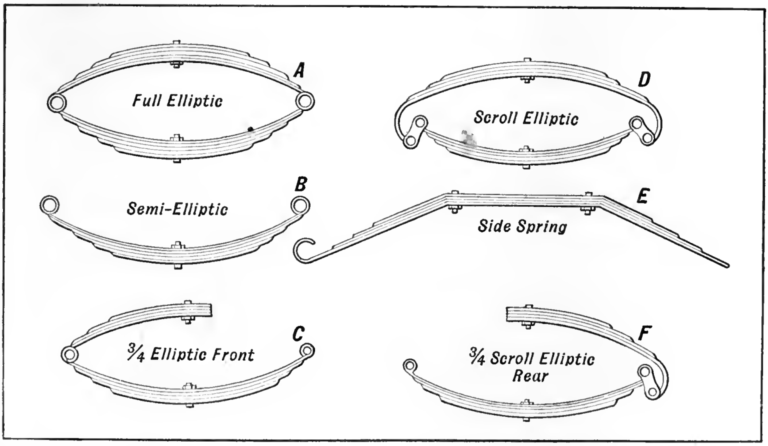


Fig. 274.—Springs Usually Employed for Supporting Motor-Car Frames and Horse-Drawn Vehicle Bodies.

The common forms of springs which have been used for supporting motor-car frames are shown at Fig. 274. That at A is a full elliptic type and consists of two semi-elliptic spring members hinged together at their ends. The semi-elliptic type, which is half of a full elliptic spring, is shown at B. The spring illustrated at C is a three quarter elliptic form used for suspending the front end of some types of cars. The scroll elliptic spring depicted at D is a modification of the full type, but it is somewhat more flexible because the lower member is fastened to the upper by means of shackles which permit more movement than the rigid bolt and eye connecting the members of form A. The side spring depicted at E is a modification of the side spring commonly fitted to Concord buggies, and while it has received some application on earlier forms of automobiles it is not used at the present time. The form shown at F is a three quarter scroll elliptic member which is very widely used at the present time for rear suspension of motor cars, especially in those chassis having upswept rear ends.

The application of the spring forms previously considered to the front end of motor-car frames is outlined at Fig. 275. The views at

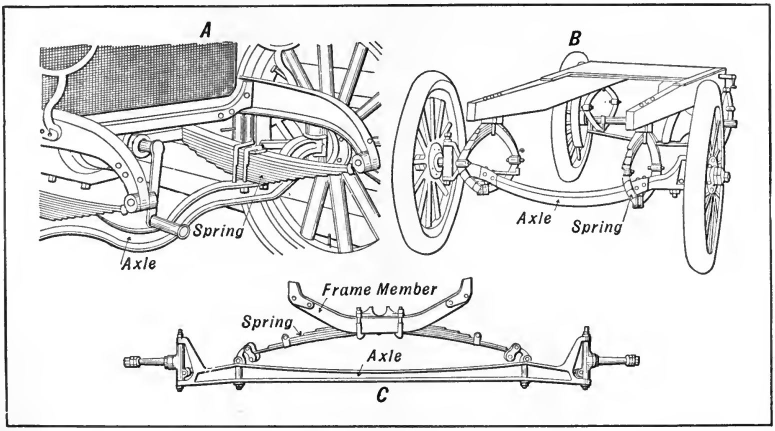


Fig. 275.—Spring Suspension Means for Front Ends of Motor-Car Frames. A—Semi-Elliptic. B—Full Elliptic of Franklin Car. C—Single Cross Spring of Ford Design.

Fig. 276 show various spring combinations used for rear-end suspension. The common method of supporting the front end is shown at Fig. 275, A, and is used on the greater proportion of motor cars. Of the rear suspensions that shown at Fig. 276, D, is popular on heavy vehicles, while the full elliptic depicted at C and the three quarter scroll elliptic outlined at E also receive general application. The semi-elliptic spring is not as easy riding as the other forms unless it is made very long and composed of but a few leaves. The various full

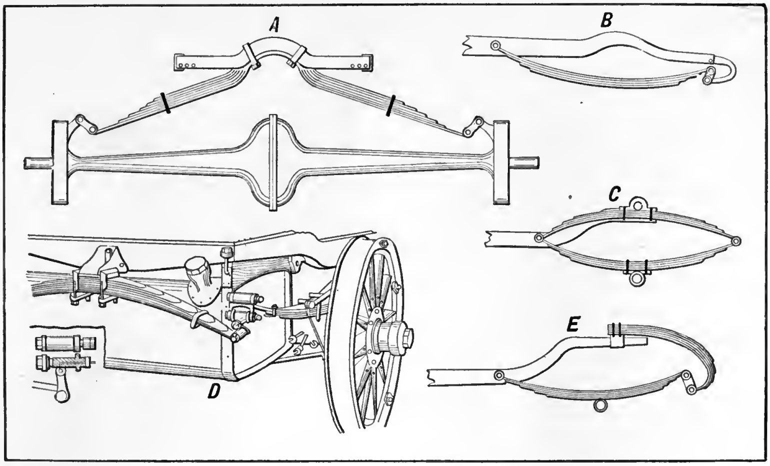


Fig. 276.—Spring Suspensions for Rear Ends of Motor-Car Chassis. A—Single Elliptic Cross Spring of Ford Cars. B—Semi-elliptic Side Member. C—Rear Support by Full Elliptic Spring. D—Platform Spring Construction. E—Three Quarter Elliptic Application.

and three quarter elliptic forms are much more flexible than a semi-elliptic of the same length and are more generally used for rear suspension where a greater degree of movement is desirable than at the front end.

When an automobile chassis is suspended on springs the frame will move in various directions. There is a certain amount of forward and backward end throw, an element of side sway and the up and down motion caused by the deflection and recoil of the spring. The object of an efficient spring suspension should be to minimize the end throw and side sway as much as possible and yet preserve the freedom of movement of the spring. It is for this reason that the semi-elliptic form is so popular for front suspension. It is a stiffer member than the others and is better adapted to carry the weight of the power plant without side away and to keep the front axle in that relation with the steering mechanism necessary to secure the best action.

In general the methods of suspension employed by automobile designers follow closely those that have been used for a number of years by manufacturers of horse-drawn vehicles. When elliptic or semi-elliptic springs of the ordinary description are used one will see that in most light horse-drawn carriages but two are employed, one being placed over each axle and parallel with it. In motor cars one seldom finds a single spring used for suspension at both ends. Usually if one spring is placed in this manner over one of the axles there are generally two arranged in the conventional manner over the other axle to provide a three-point support. A notable exception is the Ford car which employs a single cross spring at each end of the frame.

When only one spring is used in this manner radius or distance rods are required to maintain a fixed distance between the axle and the frame at the front axle, and more substantial members of the same character which will have to take the driving torque effect as well as the braking stresses will be required for the rear end. This makes two sets of radius rods necessary on each car. Most automobile designers favor the use of two semi-elliptic springs at the front end because with these there will be no need of using radius rods, as the springs are capable of maintaining the proper relation between the axle and the frame as well as resist the pushing or pulling effect due to traction, which would otherwise have to be taken by radius rods.

With practically all forms of rear suspension, especially in those which utilize the elliptical forms of springs, the inevitable forward throw makes the use of radius rods imperative. It is necessary that the proper distance be maintained between the motor mounted on the frame and the rear axle where the power is applied to the wheels. The amount of play permissible is governed entirely by the character of the driving system and with some forms there can be more latitude of movement than possible with others. In nearly all cases, however, it is essential that very nearly a fixed distance be maintained, or there will be injurious stresses on the sprockets, chains, universal joints, or gears with attendant loss of power.

A factor that has become very important is the selection of suitable alloy steels for the construction of the springs. The rapid development of high-powered automobiles which are capable of extremely high speeds had made the development of more resisting and elastic steels imperative, as the open hearth metal of standard analysis used in the manufacture of carriage springs would not make satisfactory supporting members under the severe conditions imposed by the modern automobile. For this reason, various alloy steels, such as vanadium steel and mixtures of iron, carbon, chromium, and nickel have been developed especially for fabrication into springs.

Among the other functions of springs they reduce to a certain extent the traction resistance. When the driving wheels meet obstacles the shock produced depends upon the inertia of the axle and that of the wheel which comes into contact with the impeding substance plus the resistance of the springs, which factor varies with the elasticity and design. If the springs are not sufficiently resilient the shock will lift a portion of the car as well as the wheel and axle, whereas if elastic members are employed only the axle and spring will be affected. It is patent that more power is required to surmount obstacles when stiff springs are employed, and part of the power delivered by the engine which might be used to better advantage in propelling the car is absorbed in overcoming the obstacle.

The attachment of springs to the frame and axle is a phase of the suspension problem that is important. The front end of the front springs is usually pivoted directly to the frame in spring horns forming a portion of the frame-side member. The free end of the spring is connected to the frame by a shackle to allow the necessary motion. The rear springs are usually attached to the frame in a different manner than the front member because to secure maximum efficiency the rear springs should be called upon only to support the load, and they should be relieved of all traction and torsion forces by suitable torque members or radius rods. If springs of the semi-elliptic type are used it is advisable to double-shackle them, whereas full elliptic forms should be attached to the frame by some sort of a swivel joint in order to allow the necessary motion.

The method of fastening the springs to the axle is by means of clips very similar to those that are used in carriage construction, but they are usually heavier and of better material. The spring rests upon a piece of leather or wood placed between it and the supporting pad on the axle and this material is usually curved enough to conform with the arc of curvature of the spring. This cushion is interposed between the two elements for two reasons, one of these being to avoid the strain which would be imposed upon the spring if attempt was made to attach it directly to the flat or slightly curved spring pad on the axle. The other reason is that the cushion provides a more rigid fastening because there is a certain amount of friction

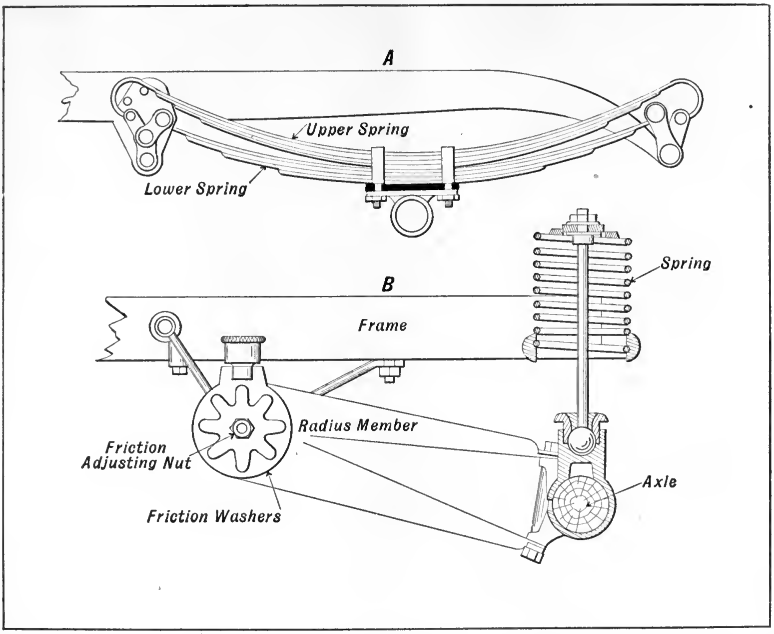


Fig. 277.—Unconventional Spring Suspensions. A—Double Semi-Elliptic Used on Winton Cars. B—Coil Spring and Shock Absorber Combination of Liberty-Brush Runabouts.

between the spring and the wood or leather piece which prevents slipping of the fastening. Authorities agree that springs should never be fastened by means of bolts passing through the leaves, as this will make a weak place in the spring which may break if stressed unduly at this point.

Some manufacturers use distinctive forms of springs developed solely for use on their product. The spring shown at Fig. 277, A, is that employed on some models of the Winton cars and is a compound form which consists of two parts which are virtually separate and distinct semi-elliptic springs. These are shackled up in such a manner that when the loads are light but one portion of the spring is used, though when the car is fully loaded both sections of the spring are brought in action. It is claimed that this method of spring construction permits easy riding under all varying conditions of load or road surface, as the strength or resiliency of the springs is governed entirely by the demands made upon it. When conditions of operation are severe the spring strength is augmented proportionately, and it becomes more resilient as the load is decreased.

The method of suspension employed on the Brush runabout is outlined at Fig. 277, B. This is distinctive inasmuch as it is the only motor vehicle produced in large quantities or in a commercial way which employs helical coil springs under tension to support the load. It will be noted that a combined shock-absorbing and radius-rod device is essential. Ths method, while extremely efficient, appears rather unconventional and is regarded as a " freak " design by most engineers. The construction is clearly outlined in the illustration and four such springs are employed, one at each corner of the frame.

How Automobiles are Steered.—The problem of steering the motor car is a somewhat different one than that of directing a horse-drawn vehicle because in the animal-drawn conveyance the shafts which are attached to the front axle are used to turn the vehicle as well as to pull it along. The front axle is usually pivoted at a central point and turns on a fifth-wheel arrangement, as shown at Fig. 278, A. When it is desired to turn in either direction the animal is guided by the reins and the axle is turned at an angle to the body sufficient to allow the vehicle to describe a curve as shown by the dotted lines. When turning sharply or in a narrow thoroughfare the construction is usually such that the front wheels may swing under the carriage body in such a way that the front axle may be parallel with the body side members or at right angles to the rear axle under extreme conditions. The stability of the carriage would be very poor if it was not for the bracing effect derived from the horses' weight between the shafts.

In most motor vehicles the propulsive force is applied to the rear wheels and the structure is pushed from behind instead of being pulled, as is the case with a horse-drawn conveyance. Obviously, it would not be practical to turn the entire axle under the car because if it described a too acute angle when the car was driven at high

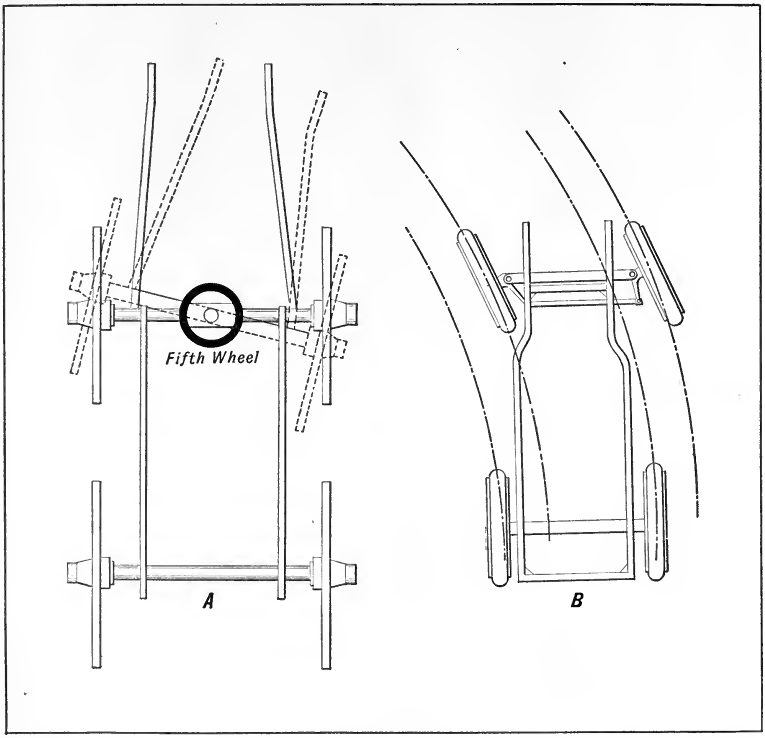


Fig. 278.—Methods of Steering Vehicles Outlined. A—Horse-Drawn Wagon Directed by Swinging Axle. B—Motor Car Steered by Movable Wheels on Fixed Axle.

speed it would be extremely difficult to control the vehicle. This was very ingeniously overcome by an engineer named Ackerman, who devised the pivoted axle which is commonly accepted as the proper method of steering automobiles.

This consisted of a fixed axle member, as shown at Fig. 278, B, which was attached to a frame by suitable springs or other means in such a way that it could only move in a vertical direction under the influence of road irregularity. The wheels are mounted on spindles carried in a yoke at each end of the axle, and when it is desired to turn an automobile only the wheels are turned instead of moving the entire axle assembly as is the case in a horse-drawn vehicle.

In order to actuate the steering knuckles, suitable mechanism that will be easily operated must be placed convenient to the driver. The earlier forms of automobiles were provided with forms of tillers very similar to those employed in controlling boats, but while these simple levers gave a certain degree of satisfaction on light cars operated at slow speeds, the development of the higher-speed vehicles made necessary more easily handled and positive forms of steering gears. The disadvantages of the tiller are that it may be whipped out of the operator's hands by road irregularities, and it is very tiresome to hold because of the continual vibration.

With the modern forms of wheel-steering devices the hands are always in an easy position, the wheels may be readily operated and because of the elimination of vibration by the feature of irreversibility provided by most steering gears of conventional construction, no road shock can loosen the grip of the driver, nor is he fatigued by continued movement of the wheel.

Steering gears are made in a variety of forms and all types have their adherents. The accepted construction is clearly illustrated at Fig. 279, A. In this the steering wheel is attached to a rod which carries a worm at its lower end. This worm meshes with a worm gear to which a steering arm is attached, and a rotary movement of the hand wheel will produce a reciprocating movement of the steering arm at the lower end of the steering column. The steering arm is coupled to one of the steering knuckles of the front axle by a connecting link and the movement imparted to the one steering knuckle is translated to the other one by means of the tiebar which joins them.

The form of steering gear outlined at B is a simpler one, but it does not incorporate the good features of the worm-gear type. It consists of a spur pinion at the end of the steering post which meshes with the spur-gear rack actuated when the hand wheel is turned in such a way that the rotary motion of the wheel is transformed to a reciprocating movement of the rack. The rack is directly attached to one of the steering knuckles by a drag link coupled to an extension from one of the steering arms. In a modification of this type a bevel gear is used at the lower end of the steering post and a bevel-gear sector is utilized to actuate the drag link. The principle of action is

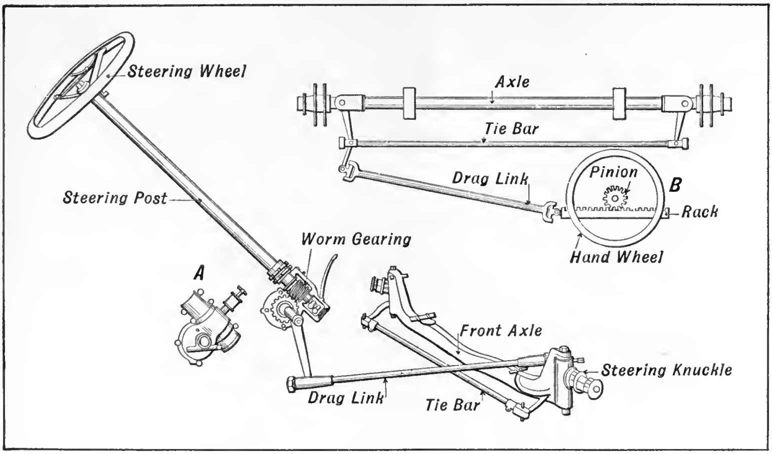


Fig. 279.—How Front Wheels of Motor Cars are Moved. A—Conventional Worm-Gear Reduction Steering Arrangement. B—Simple Rack and Pinion System Used on Light Cars.

the same as in the form described, however, and while either of these forms may be applied to light cars and make for ready control because they are quick acting they are not desirable on heavy vehicles because they do not provide the feature of irreversibility which is necessary.

The factor of irreversibility in steering gearing is one that was formerly a point of contention among authorities on automobile construction. It was argued that the irreversible form does not provide that quick action which is considered necessary to secure prompt control of the car. At the other hand, the strictly reversible gear such as the spur rack and pinion, which is especially quick acting, will tire the operator whenever the car is operated on rough roads, as every inequality of the road service will tend to produce a corresponding side motion of the wheel which will mean considerable play at the rim of the steering wheel.

Some engineers who contended that the worm and sector gear were liable to wear devised combination forms in which a screw and

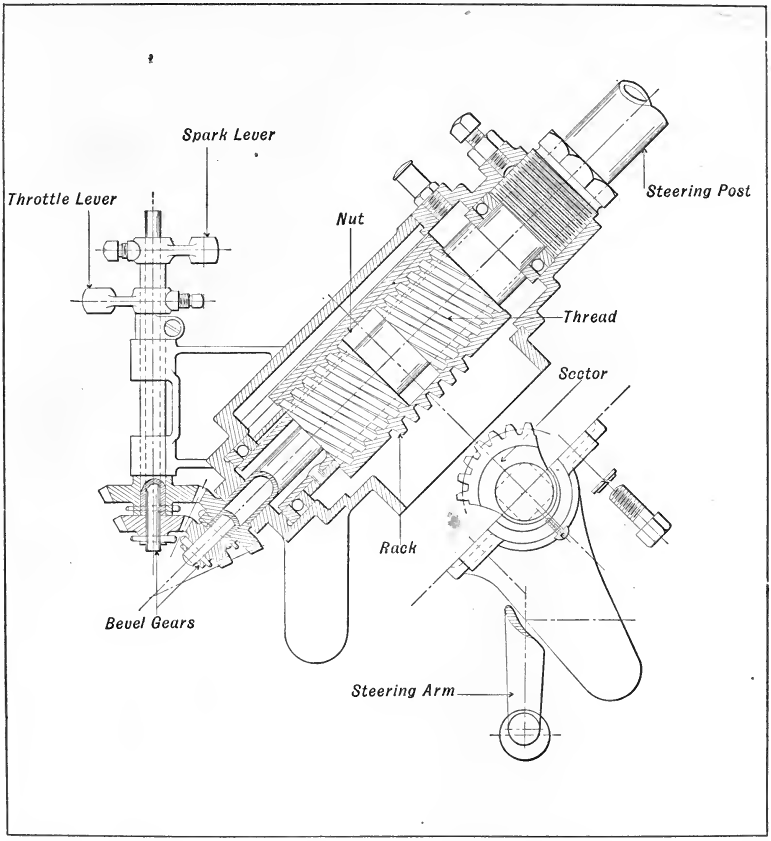


Fig. 280.—Unconventional Steering Gear Employing Threaded Steering Post and Movable Nut with Rack to Engage Sector on Steering Arm Shaft.

nut principle was combined with a rack and sector gear, the object being to provide a largely increased bearing surface on the threads and gear teeth and in this manner reduce wear.

A gear of this type is shown at Fig. 280. The nut or internally threaded member is held from turning by various methods, such as flattening one side and having this in contact with the walls of the casing, by the use of keys or dowel pins, or merely by the pressure of the rack and sector shown in illustrations. The advantage of this form of steering gear is that it is wholly irreversible and at the same time a minimum of effort is needed on the part of the driver to properly control a very heavy car. The amount of movement of the nut, up and down, is regulated by the pitch and angle of the thread and as the nut is provided with a spur rack its rectilinear motion is transformed into an oscillating movement of the steering arm attached to the spur-gear sector.

The worm and segment type of steering gear is without doubt the most popular with automobile manufacturers of this country and Europe. It is simple, compact, and positive in action. The steering post carries a worm at its lower end, as shown at Fig. 281. This in turn meshes with a suitable worm wheel or segment attached to the steering arm. The worm when turned will produce a fore and aft movement of the steering arm which in turn is transmitted to the wheels by suitable leverage. This type of gear must be maintained in perfect adjustment and be well lubricated at all times. The greatest defect is the wear that will exist between the worm and worm-gear teeth, and the difficulty of devising any really practical method of taking up the play. The constant oscillations of the vehicle wheels will cause the sector teeth and worm thread to wear at one place, which corresponds to the straightahead position of the gear.

This may be taken up in most forms by the use of eccentric bushings in which the sector shaft is mounted, these being moved in such a way that the sector teeth are brought into closer engagement with the thread of the worm. This method is not desirable because if the eccentric bushings are turned enough to take up the lost motion existing between the teeth, the change in worm-gear position would cause binding between those portions which had not worn as much and which were brought into play only when it was desired to turn the wheels to nearly the extreme angular position. The preferred method is that outlined at Fig. 281. In this a full worm wheel is used instead of a sector and when wear occurs at one point the worm wheel is removed, the hand wheel and worm are given a complete turn, and the worm wheel is replaced in such a way that a new set of teeth on both worm and worm gear will be in mesh.

With all conventional forms of steering gears the object has been to get a complete sweep of the front wheels, that is to turn them from one extreme position to the other with about one and one half

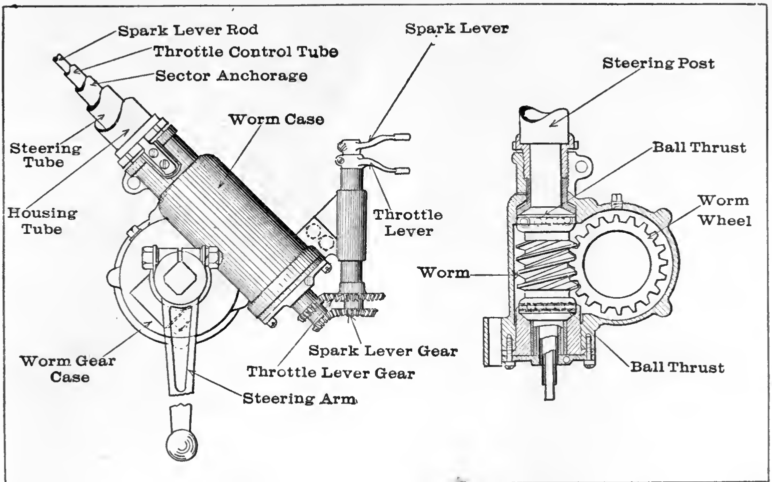


Fig. 281.—Construction of Worm and Worm-Gear Reduction Gearing for Steering Purposes.

turns of the hand wheel. Anything slower than this will be so tardy of action that it will be difficult to steer the car properly and quickly at anything but low speed. On some heavy commercial vehicles, however, it is necessary to provide lower reduction, and two or two and a half turns of the steering wheel are sometimes necessary to produce the proper degree of movement of the front wheels. This is not a point that can be seriously objected to when one considers the low speed of the conventional motor truck. On high-speed cars some authorities claim that one turn of the wheel to produce a full movement of the steering wheel is entirely satisfactory, as it permits handling the car with minimum lag and makes it quick to respond to the control gearing at all speeds.

It is common practice on most motor cars to combine the motor-controlling levers with the steering gear in such a way that the speed of the motor may be varied as desired without the operator removing his hands from the steering wheel. The manner in which this may

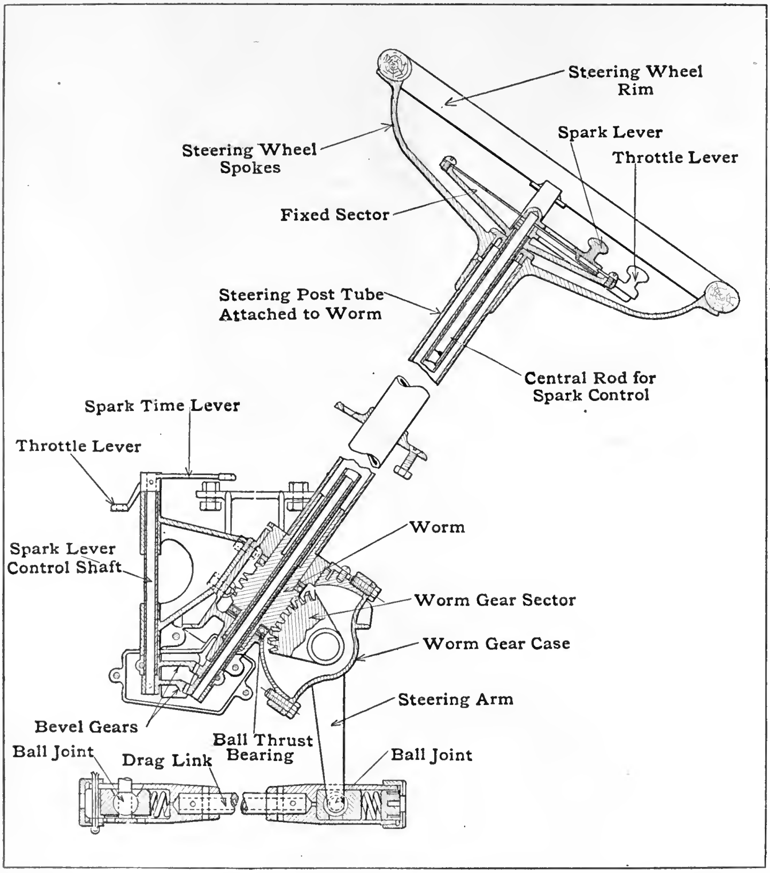


Fig. 282.—Typical Steering Post Assembly Showing Hand Wheel and Motor Controlling Levers. Sectional View of Worm and Worm Wheel and Steering Arm Connecting Member.

be accomplished is clearly shown in the steering-gear design depicted at Fig. 282. In this the steering wheel is attached to a tubular steering post, through the center of which a rod mounted inside of two concentric tubes is passed. The outer tube is anchored at the bottom end of the steering-gear casing and carries the sector on which the spark and throttle levers move. The short lever is attached to the rod passing through the center of the assembly, and this in turn actuates by means of bevel gearing an auxiliary control shaft mounted in front of the steering-gear assembly. The long lever is attached to the tube which surrounds the central rod, and this member also carries a gear at its lower end which engages a tube surrounding the spark-lever control shaft at the front of the steering gear. The spark timer or commutator is attached to the upper lever while the carburetor throttle is operated from the lever immediately below that controlling the spark-timing device.

As the sector is anchored at the lower end of the gear case it remains stationary when the steering wheel is turned and the motor-control levers always maintain a fixed relation to each other and the operator. All gearing is enclosed and thoroughly lubricated, and as there is but little chance for dirt to get in, the mechanism is very enduring. Ball-thrust bearings are provided above and below the worm to take the end thrust which results when it is turned. This makes the gearing much easier to operate than would be the case if the considerable amount of end thrust present was taken on plain bearings.

Front Axle Forms.—Various front axle constructions used in automobiles follow a common design and the same general principle of action prevails in all. Front axles differ from each other only in matters of minor constructional detail, such as the type of steering knuckles used and whether the axle is a one-piece forging or a built-up structure. Axles of good design are shown at Fig. 283. That at A is composed of a one-piece I-section drop forging of steel which has the advantage of having the steering-knuckle yokes and the spring pads formed integral. This is the type most generally used because it is exceptionally strong and when properly designed is not unnecessarily heavy.

One of the front hubs is shown in section in the plan view of the axle depicted at A. The hub is mounted on ball bearings, which in turn are supported by the spindle which forms part of the steering knuckle. A long through bolt passes through the steering knuckle and acts as a bearing for it to swivel on. Steering arms project from each knuckle and are joined together by a tiebar.

The construction of the axle depicted at B is practically the same in general design as that shown above it. It differs in the important

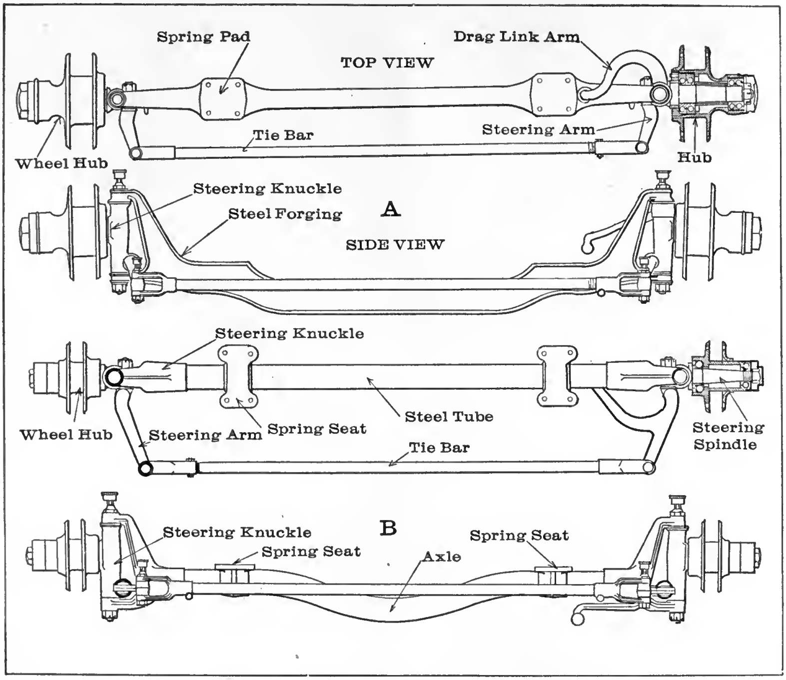


Fig. 283.—Typical Front Axle Types. A—Forging of I Section. B—Tubular Axle.

respect that the axle proper is formed of a piece of steel tubing to which the separately forged yokes and spring seats are secured by brazing. Those who favor the tubular axle claim greater flexibility and lightness combined with adequate strength, while the adherents of the I-beam construction advance the argument of exceptional strength and contend that flexibility is not a point of moment compared to rigidity of the structure. As a general rule, tubular axles are employed on light cars, while the heavier forged form is utilized extensively on the larger vehicles. Various forms of steering knuckles and bearings used for mounting the front wheel are shown at Fig. 284. At A an Elliot type knuckle, which is provided with a roller-thrust bearing at its upper end to take the thrust due to the weight of the car, is shown. The wheel hub is mounted on taper-roller bearings secured to the spindle in the usual manner. Another

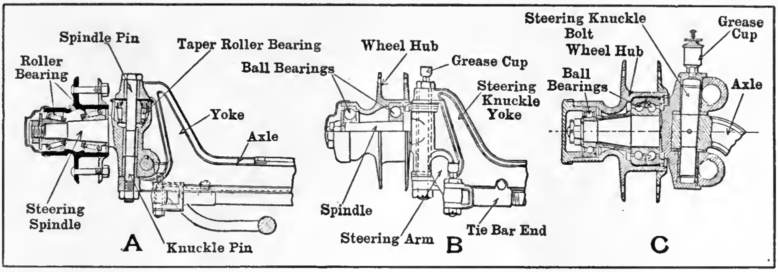


Fig. 284.—Typical Front Hub and Steering Knuckle Designs. A—Elliot Type Hub with Taper Roller Bearings. B—Front Hub Mounted on New Departure "Radax" Ball Bearings. C—Mercedes Type Steering Knuckle, Hub Mounted on Single and Double Row Bearings.

Elliot knuckle is depicted at B, but in this construction the front hub is supported on ball bearings of the cup and cone type. The steering knuckle depicted at C is a modification of the Mercedes design, and in this the yoke forms part of the wheel spindle and oscillates on a pin carried by the end of the forged steel axle. Special attention is directed to the form of ball bearings utilized for supporting this hub. Practically all of the weight is taken by a large New Departure double purpose bearing specially adapted to support both end thrust and radial loads. This forms a very effective bearing and is often used at points in the motor-car chassis where severe loads are to be resisted. The general construction of these steering knuckles and the mode of application of the bearings on which the hubs revolve are so clearly shown that further description is not necessary.

Typical Power Transmission Systems.—One of the factors making for motor-car efficiency is the system of transmission employed by which the power delivered by the engine is transmitted to the rear wheels, and the most efficient system is obviously that which will deliver the power to the rear wheels with minimum loss. The common methods of power transmission are outlined at Fig. 285. That at A is the system formerly used on many light cars which derived their power from a single-cylinder engine placed lengthwise in the chassis. The drive from the sprocket on the planetary gearset is by means of a chain to a sprocket on the differential gear of the rear axle. This was one of the most direct methods of transmission possible and was remarkably efficient as long as the chain was kept clean, properly oiled, and in correct adjustment. The efficiency of this arrangement was very high, and about ninety per cent of the engine power was delivered to the wheels on the direct drive and about seventy-five per cent when the planetary gearset was in operation.

The system shown at B was formerly very popular on all classes of touring cars, but is seldom used at the present time except in heavy commercial vehicles. With this system the differential gear is carried adjacent to the gearset and driving shafts extend therefrom to sprockets at each side of the frame. The drive from the countershaft member is by means of driving chains to sprockets on each rear wheel. The wheels are mounted so they revolve on a stationary axle. It is believed that this construction is stronger than the live axle for heavy vehicles, and it is also used because it permits the designer to obtain a double reduction and very low ratios of speed, which make it very suitable for motor-truck service. The efficiency of this method of driving is lower than that in which either chains or gears are used alone, and even when the gearset is in the direct drive position or high-speed ratio there is a loss of twenty-five per cent in transmission, which gives a net efficiency of seventy-five per cent under most favorable conditions. When on the lower ratios, which demand the use of the change-speed gearing, the efficiency is reduced to about sixty per cent.

Various forms of shaft-drive systems are popular at the present time and the two methods of employing shafts differ merely in detail. In the diagram shown at Fig. 285, C, two universal joints are employed and a length of driving shaft. One of these joints is mounted at the end of the gear box on the power plant unit, while the other flexible member is attached to the differential housing. The drive

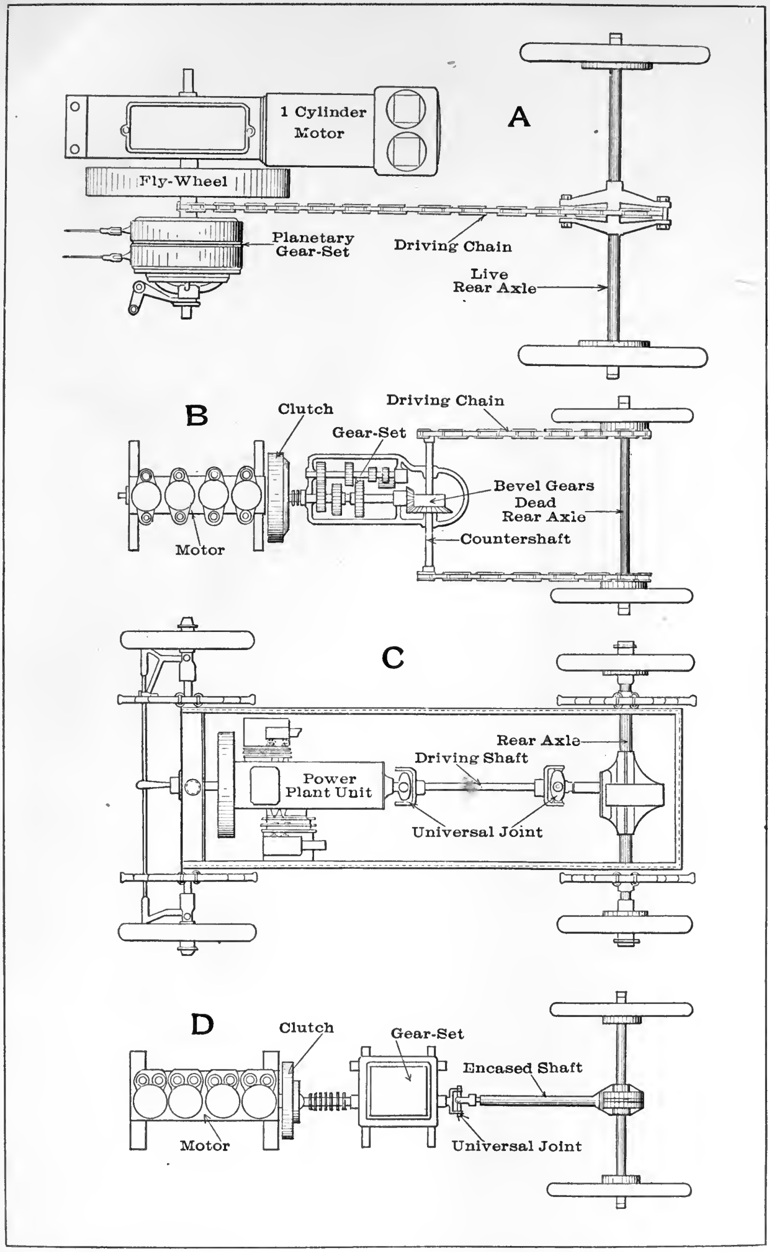


Fig. 285.—Methods of Power Transmission Employed by Motor Car Designers. A—Single Chain Drive from Planetary Gearset to Live Rear Axle. B—Side Chain System. C—Drive by Exposed Shaft Having Two Universal Joints. D—Drive Shaft Enclosed in Torque Tube Needs but One Universal Joint.

from the shaft to the wheels may be by bevel or worm gearing and when this system is employed it is necessary to use some form of radius rod member to keep the axle in proper relation with the frame.

When the method depicted at D is employed but one universal joint is needed. The driving shaft is encased in a tubular member usually attached to the frame in such a manner that it serves as a radius member and permits the axle to move up and down under the influence of rough road surfaces, but does not permit end movement of the axle. The efficiency of the shaft-driving systems is very high compared to the double-chain drive and as all parts are always en-

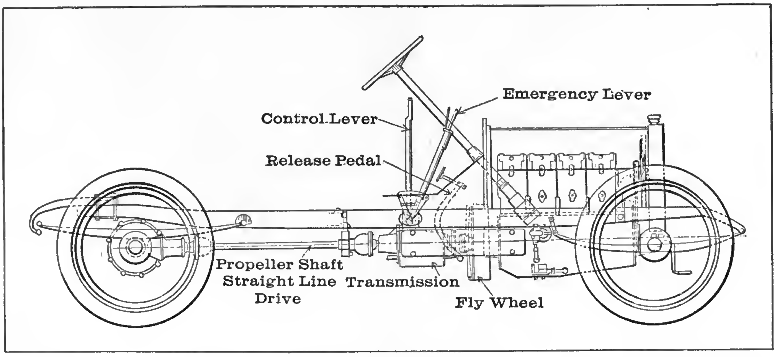


Fig. 286.—Chassis of Knox Car, in which Straight-Line Driving Shaft is Utilized, which Permits Power Transmission with but Minimum Loss.

closed and run in lubricant the efficiency may be conserved. While the power loss with a bevel-gear and shaft-driving system is apt to be a little higher than the single-chain method when both are new, deterioration is apt to be more rapid in the chain-driven cars. If care is taken to install the power plant so the propeller shaft will be on a straight line with the engine crank shaft, as depicted at Fig. 286, but fifteen per cent of the power will be lost in transmission. If the driving-shaft angle increases the efficiency will be lower. A safe rule for estimating this is given by some authorities as one per cent loss for each degree of shaft inclination.

Rear Axle Forms.—In any motor car the rear axle is an important member as it combines two functions, one being that it is depended upon to support part of the car weight and that it must also drive the vehicle. The rear axle forms in common use are known as the "live" or "dead" types. The latter is the simplest and is built on the same principle as that generally utilized in horse-drawn vehicles. This construction serves merely to support the weight of the car and the power of the engine is delivered to the wheels by means previously described.

Two types of live axles are shown at Fig. 287. That at A is the simplest form and in this the wheel hubs are mounted directly on the axle shaft, and these members are depended upon to carry the weight of the car as well as to transmit to the wheels the power delivered to the bevel gearing and the propeller shaft. In this construction the axles revolve in roller bearings carried by the axle housing. The form shown at B is known as the "floating type" because the wheel hubs are mounted directly on the substantial housing member which is called upon to support the weight of the car. The wheels can revolve freely on the housing because they are mounted on ball bearings. The axles float in the housing and are called upon only to transmit power to the hubs and are not depended upon to sustain any of the car weight.

The live axle depicted at A has been adapted to a certain extent on light cars, but the full floating type depicted at B is much more efficient and is used on heavy vehicles. It will be evident that should the simple form of live axle deflect under load the shafts will bind and considerable loss of power will obtain. In the construction outlined at B the substantial housing members have ample capacity to sustain the load, and as the driving shaft does not become cramped through deflection it will deliver the power to the wheels much more efficiently. A strong advantage of the floating type rear axle is that the driving shafts and differential gearing may be removed without relieving the housing of the car weight. If it is desired to take the simple live axle shown at A apart it will be necessary to remove it from the car.

The fixed or stationary axle construction is clearly shown at Fig. 287, C. In this the wheel hubs are mounted on ball bearings which permit them to revolve about the fixed axle spindle. The hubs are turned by chain connection with suitable driving sprockets on a countershaft. The advantage of the fixed or stationary axle construction is that it is a much simpler assembly than the live axle forms, and as it may be constructed of few pieces it is apt to be considerably

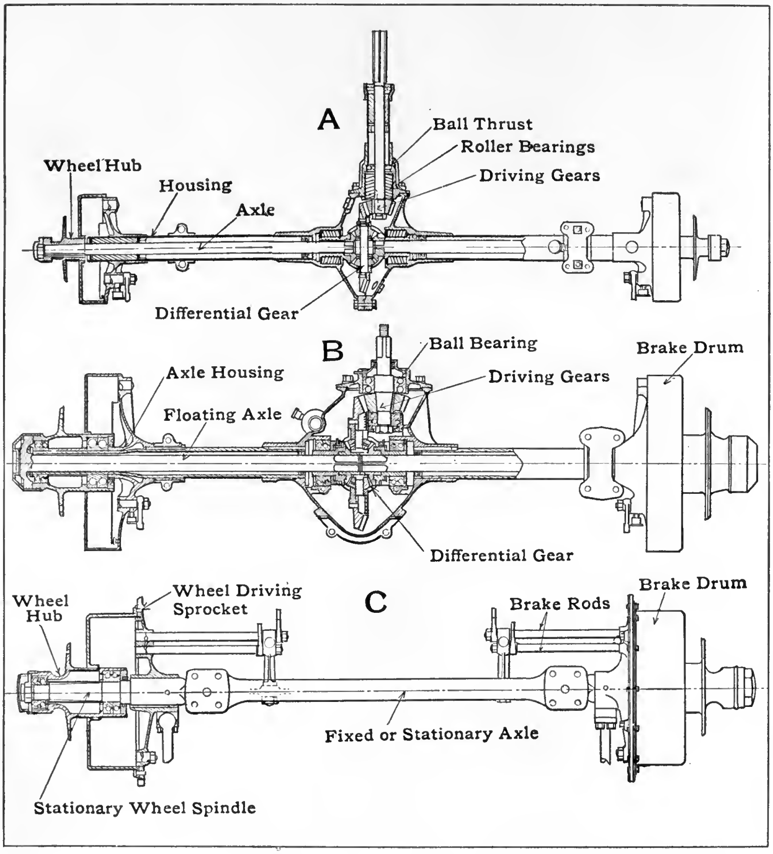


Fig. 287.—Rear Axle Types Generally Used. A—Live Rear Axle Using Shafts which Transmit Power and also Carry Weight Equipped with Roller Bearings. B—Full Floating Type Bevel-Gear Drive Axle. C—Stationary Axle with Chain Drive to Free Wheels.

stronger than the built up live axles. It is contended that the lighter axle, which is practically free from any delicate mechanism, is more desirable because there is less weight carried directly on the tires. In the live axle forms some method of driving must be provided and some form of differential gearing must be included in the rear housing. It is contended that while this construction is very suitable for light cars such as roadsters, or touring vehicles, that it would be extremely heavy if it was built of adequate strength to resist the stresses incidental to motor-truck operation.

In the fixed or stationary axle with the wheels independent of each other, a differential gear must be provided just as much as in the live axle forms. This member is usually driven by gearing and must be installed on some form of a countershaft arrangement which

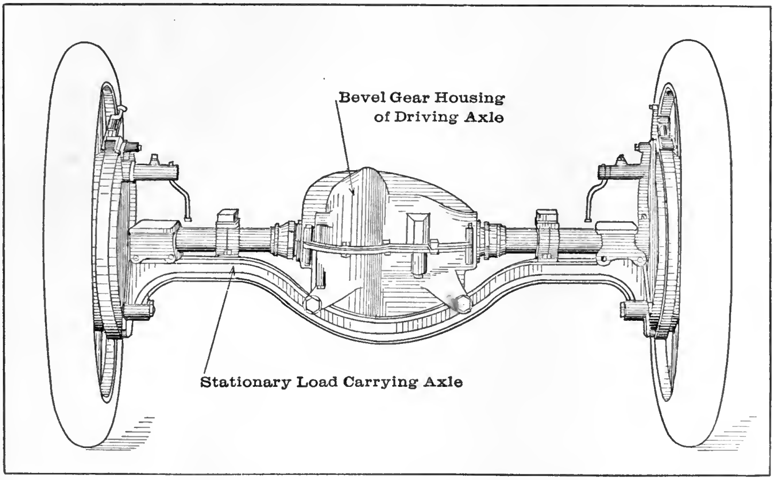


Fig. 288.—Combined Live and Stationary Axle which Combines Good Features of Both Types and Eliminates All Objections to Either. The Strongest Possible Construction.

is attached to the frame. It is contended that mechanism supported by the frame which is mounted on resilient springs will not be so apt to get out of order as that which is attached directly to the axle, and which is kept from direct stress of the road shock only by means of the more or less resilient tires with which the wheels are provided.

Axles have been evolved in which engineers sought to combine the strength of the dead axle with the efficiency of the live axle. One of these combinations is shown at Fig. 288. It consists of a stationary load-carrying axle forging on which the wheels revolve, this serving to take the direct load of the car as well as serving as a support for the bevel gear and differential housing that receives the power of the engine and directs it to the wheels by means of suitable shafts extending thereto from each side of the gear box. These composite forms are necessarily considerably heavier than either the live axle or the fixed axle forms as they are a combination of both, and as they are more expensive in first cost and add a large item to the unsprung weight of the car they are used very seldom at the present time.

Purpose of Differential Gear.—One of the most important elements of any form of automobile-driving system is the differential gear, but as this is usually placed at a point where it is not easily seen by the motorist and as but very little trouble is experienced from this mechanism, many owners of cars are not aware of its existence and do not realize the important work performed by this relatively simple component. Without a differential gear it would be difficult to control the machine when driving around corners, so this really performs an important function with both steering and driving systems.

When turning corners with a four-wheel vehicle the outer wheels must turn at a higher rate of speed than the inner ones because they are describing a larger arc of the circle. The more sharply the vehicle is turned the greater the difference in velocity between the inner and outer wheels. In a horse-drawn conveyance all the wheels are independent of each other and may all revolve at different speeds if necessary, without interfering with each other or impairing the action of the conveyance. In an automobile different conditions prevail because while the front wheels are usually independent of each other, the driving wheels must be connected together so that each will receive its share of the energy produced by the motor and will perform its quota of the work incidental to propelling the vehicle.

In order to permit one of the driving wheels to turn at a lower speed than its mate in rounding a corner the balance or differential gear is used. Its simplest application is shown at Fig. 289. From this it is patent that the driving axle is split in the center and that the wheels are mounted on and driven by distinct shafts. At the inner end of each shaft a bevel gear is carried, these being firmly secured to the axles so they revolve with them. The main bevel-driven gear, which is actuated by the driving pinion turned by the engine

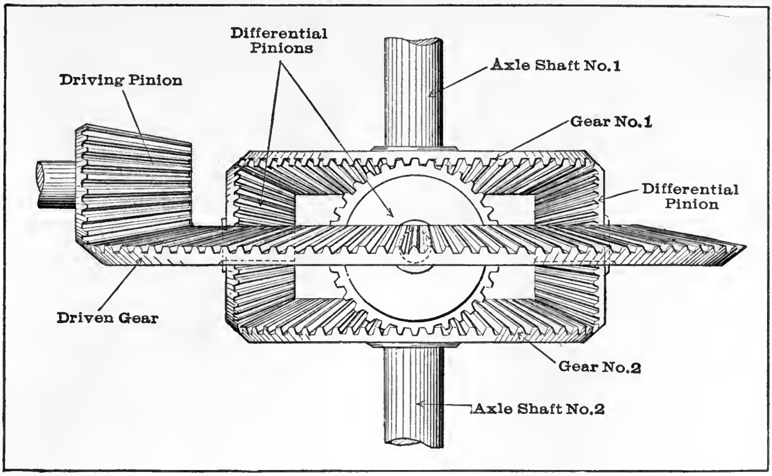


Fig. 289.—Illustrating Differential Gear Action when Applied to Bevel-Gear Drive Axle.

shaft, is mounted independent of the axles and is coupled to them by means of small bevel pinions which are applied so that they will drive the gears on the axle shafts. Assuming that all the gears are in mesh, as outlined, and that power is being applied to the driven gear, and that the resistance to traction is the same at both rear wheels, the entire assembly comprised of driven gear, the differential pinions attached to it and the axle shafts revolve as a unit.

If the resistance against the driving wheels varies so one wheel tends to revolve faster than the other, the differential pinions will not only turn around on the studs on which they are mounted, but at the same time will run around the gears on the axle shafts, because the bevel-driven gear is carrying the studs on which the differential pinions revolve forward. When turning a corner the outer wheel must turn so much faster than the inner member that it is just the same as though one of the wheels was held stationary and the other turned. If both wheels are turning forward at the same speed, the differential pinions remain stationary and act simply as a lock which forms a driving connection between gear No. 1 on axle shaft No. 1 and gear No. 2 on axle shaft No. 2. This will mean that both wheels must turn in the same direction as long as the work is uniformly distributed. Just as soon as the resistances are unequal the differential pinions will turn on their supporting stud, and one member may turn at comparatively slow speed while the other revolves at a much faster rate.

The action of the differential pinions may be clearly understood by reference to Fig. 289 and giving due consideration to the following principles: The same resistance at the point of contact between the driving wheels and the ground prevents the pinions from revolving on their own studs, and in this case they are carried around by the supporting members and the ring gear. If the resistance upon axle shaft No. 1 is greater than that on axle shaft No. 2, the ring gear will rotate forward with the wheel offering the least resistance and the differential pinions will turn on their studs and run over the surface of the gear which tends to remain stationary, this being the one against which there is the greatest resistance. The differential pinions can thus turn independently of one gear wheel and run over its surface without turning it, and at the same time act as a clutching member of sufficient capacity on the other gear and axle to carry them in the same direction as the ring gear and at a ratio of speed which will depend upon the difference in resistance between the driving members and the ground.

While the differential gear described is of the bevel pinion type, other forms have been devised in which the differential action is obtained by means of spur gearing which utilizes the same principle of compensation. Various friction and leverage combinations have been adapted in an endeavor to secure a differential action, but these have eventually been displaced by the simpler and more efficient geared forms. The differential gear which utilizes bevel pinions is the form that is more generally used, and has proved to be the most efficient and enduring. The differential gear is usually incorporated in the rear axle if the drive is by shaft or single chain, and in the countershaft if transmission is by means of side chains. The construction of typical differential gears and bevel-driving gear assembly is clearly shown at Figs. 290 and 291; the former is utilized on light vehicles and is mounted on flexible roller bearings, while the other

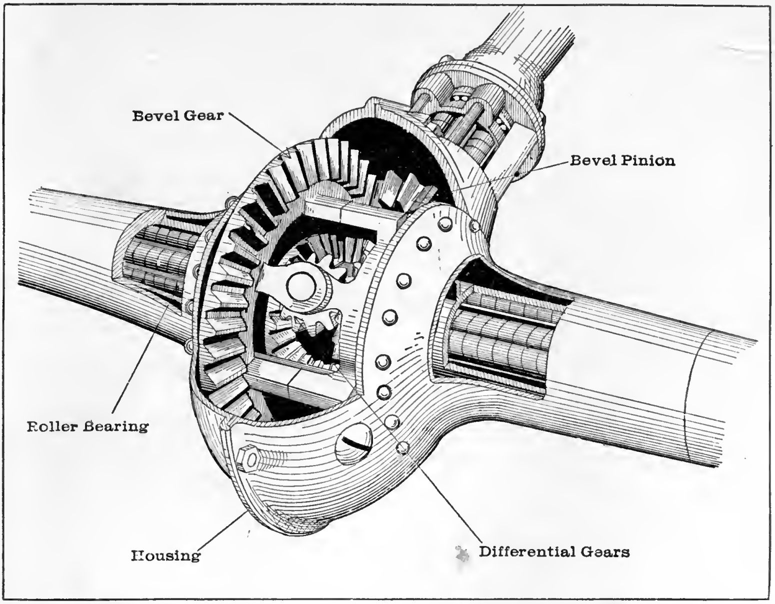


Fig. 290.—Bevel-Gear Drive Assembly of Ford Light Cars Mounted on Hyatt Flexible Roller Bearings.

construction is a type more suitable for heavier cars and is mounted on tapered roller bearings.

Worm-Gear Driving.—A number of designers have used worm gearing in connection with shaft-driving systems instead of the bevel gears so generally adapted. The greatest development of worm driving has taken place abroad, and very efficient and enduring mechanisms have been evolved. The advantages of the worm gear are more apparent in motor-truck construction than in pleasure-car practice, though it has been used to advantage in both classes of vehicles. A high degree of efficiency has been obtained by using worms of peculiar tooth formation which have a spiral angle often approaching 45 degrees. Such worms may have from six to ten or twelve threads, and they are perfectly reversible, when contrasted to the single-threaded worm used in steering gears, which are an irreversible form. Obviously the worm employed for driving an automobile must be perfectly reversible to be practical, as very often conditions will be

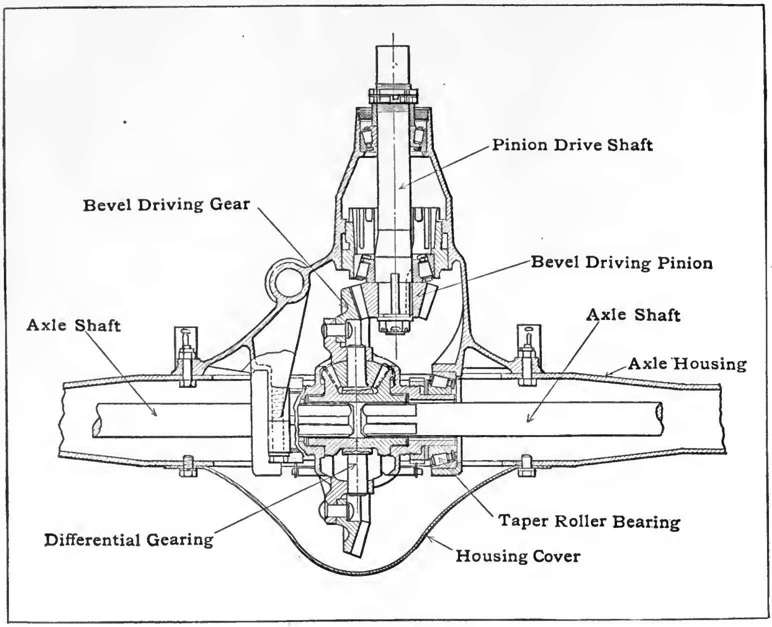


Fig. 291.—Bevel-Gear Drive Assembly Mounted on Timken Tapered Roller Bearings.

such that the rear wheels and worm gear to which they are attached must turn the worm and driving shaft, as in descending hills, with the rear axle overrunning the engine.

This form of gearing offers many inducements and has positive advantages which commend it as a means of direct final drive. Any range of reduction that would be likely to be needed may be obtained with but a single pair of worm gears, and reductions of twenty to one may be as easily accomplished as securing the higher ratios without the efficiency of the combination being affected. It would not be possible to obtain as low speed reduction as possible with worm gearing by the use of a single set of bevel gears or a single pair of sprockets and chain connections, because the driven member would have to be of such large size that it would be difficult to place it within the confines of an ordinary axle. It is for this reason that most motor-truck manufacturers use a combined bevel gear and chain drive and a double reduction of speed between the engine and the rear wheel.

Among some of the advantages advanced in favor of worm gearing may be cited: It is silent in operation; when properly designed it will transmit eighty-five to ninety per cent of the engine power to the rear wheels on direct drive, and it is extremely enduring. Its efficiency under ideal conditions is equal to the most accurately machined and finely adjusted bevel gearing, and instead of the efficiency becoming less as the gearing wears, it actually becomes more silent and freer running with use.

Many of the more progressive manufacturers of automobiles are giving the worm and worm-gear drive that consideration which means its eventual adoption. It has been used with success in pleasure-car applications, but its greatest field of usefulness will undoubtedly be

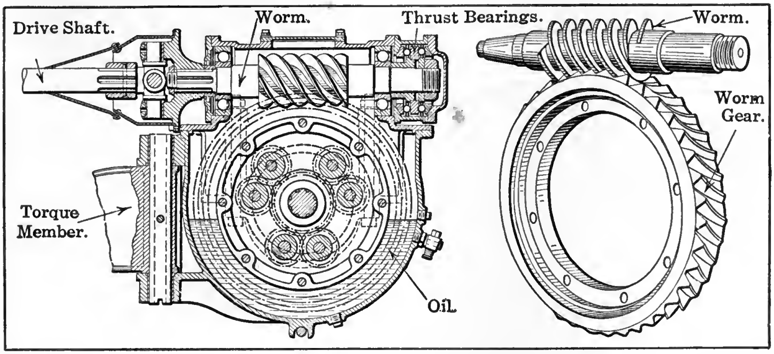


Fig. 292.—Worm-Gear Driving Assembly Utilized on Pierce Motor Trucks and Form of Worm and Worm Wheel Utilized in Power Transmission.

the commercial vehicle industry because of its undoubted superiority over all other forms of gearing from which considerable reductions in ratio are demanded and where the efficiency of the transmission system should be conserved as much as possible. A typical worm-gear assembly and the method of mounting the worm in connection with the shaft drive is shown at Fig. 292, while the illustration at

Fig. 293 shows clearly the application of worm and worm-wheel drive in a live or floating axle construction.

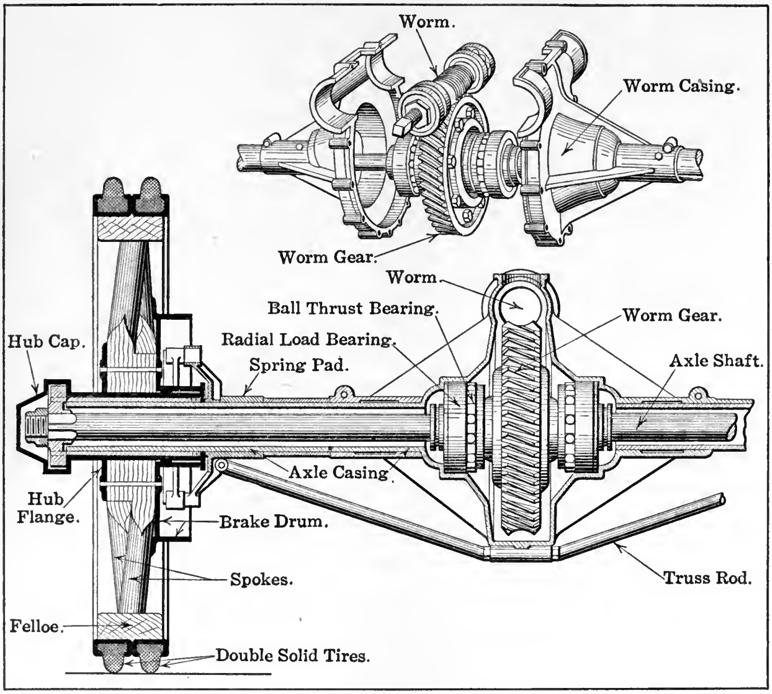


Fig. 293.—Worm-Gear Driving Axle Used on Dennis (English) Motor Cars.

Axles Employing Double Reduction Gearing.—The simplest form of axle in which two gear reductions are necessary is the stationary or dead axle, but it must be used with the jack-shaft combination previously described. There is one gear reduction by means of bevel driving gearing in the countershaft assembly, and the ratio between the driving sprockets and the driven members attached to the wheel may be altered so a wide range of speed may be obtained. The use of a separate countershaft assembly is favored by the majority of builders of motor cars who find it necessary to use two speed reductions in the driving gearing, and one of the objections which has been advanced against the use of exposed driving chains has been overcome in many designs by the use of oil-tight chain cases that protect both chains and sprockets from grit and dirt and insure efficient operation because the chains operate in an oil bath.

If a driving chain is kept properly adjusted and remains clean and well oiled its efficiency will be very high, and chain cases are very desirable attachments to attain these ends. The usual form of chain case is depicted at Fig. 294. In this construction the case proper is composed of an aluminum casting which is also utilized as a distance member to maintain a fixed relation between the front sprocket and that on the driving wheel. When the cover is in place

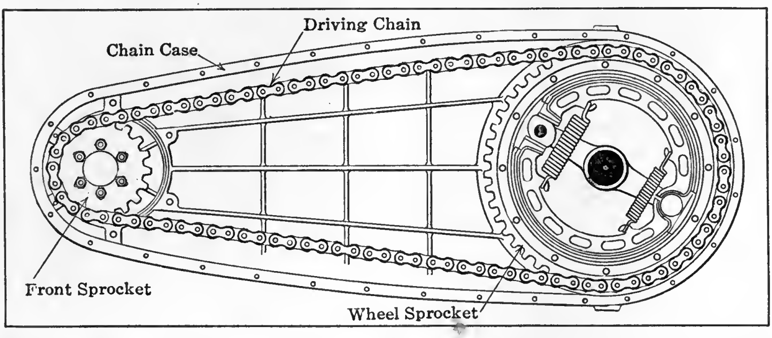


Fig. 294.—Method of Enclosing Driving Chain in Oil-Tight Casing to Secure Efficient Driving and Long Life of Mechanism.

the assembly is oil-tight and the chain and sprockets always receive adequate lubrication, which tends to greater endurance and maintenance of efficiency.

Some engineers do not favor the chain-driving method, and when a double speed reduction is necessary between the motor and the driving wheels it is incorporated directly in the rear-axle structure. A combination axle of this type, known as the "Torbensen," is depicted at Fig. 295. This is in reality a combination of the live and dead axle forms and has been designed specifically for application in motor-truck work. The differential gear is carried in the casing attached to the back of the fixed axle and receives power from the engine through the drive shaft and a pair of bevel gears. The wheels are mounted directly on the ends of the fixed axle and are driven from the differential gear by means of axles extending therefrom and carrying driving pinions of the spur type which mesh with internal

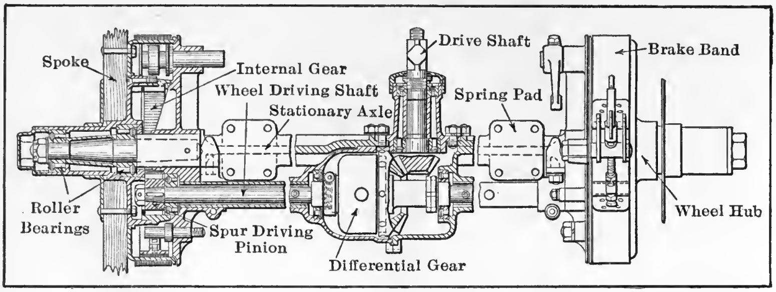


Fig. 295.—Sectional View of Torbensen Axle for Motor Trucks which Combines Features of Both "Live" and "Dead" Rear Axle Forms and which Utilizes Two Driving Gearing Sets.

gears attached to the wheels. It will be evident that one reduction of speed is obtained at the bevel gearing, and this would be further

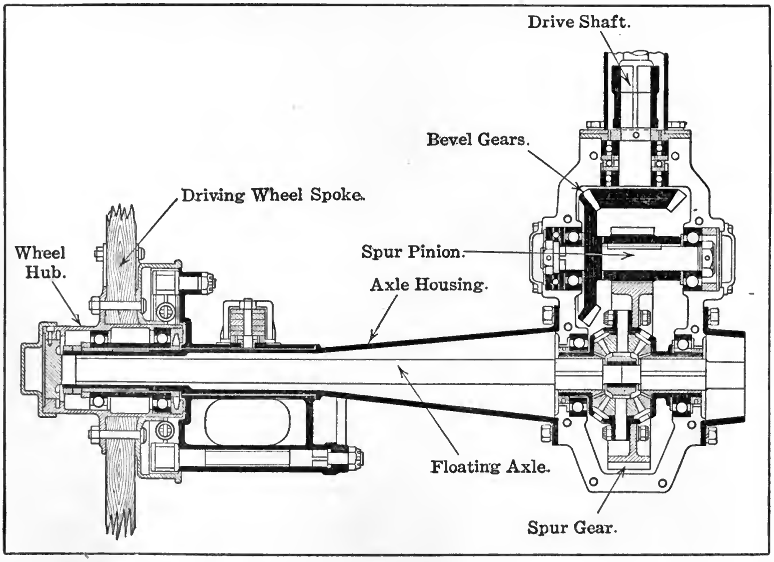


Fig. 296.—Live Rear Axle with Combined Bevel-and Spur-Gear Final Drive.

reduced by the difference in ratios between the spur-driving pinions and the internal gears carried by the wheels.

The live-axle form shown at Fig. 296 is that used on some of the Peugeot (French) cars and also uses bevel and spur reduction gears. In this case, however, but one spur gear is used to drive both wheels, this being attached directly to the differential gear case, and the wheels are turned by live floating axles. The first speed reduction is by means of the bevel gears, one of which is driven by the motor, the other being attached to the countershaft, which also carries the small spur-driving pinion, which meshes with the large gear on the differential case. The efficiency of either of these axles will be about the same as that of the combination countershaft and side-chain drives, but those who favor the latter construction advance the argument that combining a double reduction on the axle makes for greater unsprung weight than is desirable, whereas carrying the countershaft on the frame makes it possible to support it on springs, just as the greater part of the power-generating and transmission mechanism is.

Utility of Motor-Car Brakes.—One of the most important of the components of the motor-car controlling system is usually carried with and forms part of the rear construction, this being the braking means which is utilized to bring the vehicle to a stop when it is desired to arrest forward or backward motion. It will be evident that in a horse-drawn vehicle the animal drawing it can be used as a brake, but that in any form of self-propelling conveyance it is essential that some means of stopping be included in the construction. Even if the clutch was operated in such a way that the motor was disconnected from the driving wheels the conveyance would continue to move because it had acquired a certain momentum which would increase in value with the weight of the car and the speed at which it was driven.

On some forms of horse-drawn vehicles, particularly those of large capacity, some form of supplemental retarding member must be provided to assist the braking effect of the animal, which may not be sufficient to stop the vehicle when descending grades or when operated with some degree of speed on the level.

A simple form of shoe brake, such as used on a horse-drawn conveyance, is shown at Fig. 297. This consists of a brake block of wood or other material carried at the end of a fulcrumed lever, which in turn is joined to a pedal by a connecting link. When it is desired to bring the vehicle to a stop, a moderate degree of pressure at the

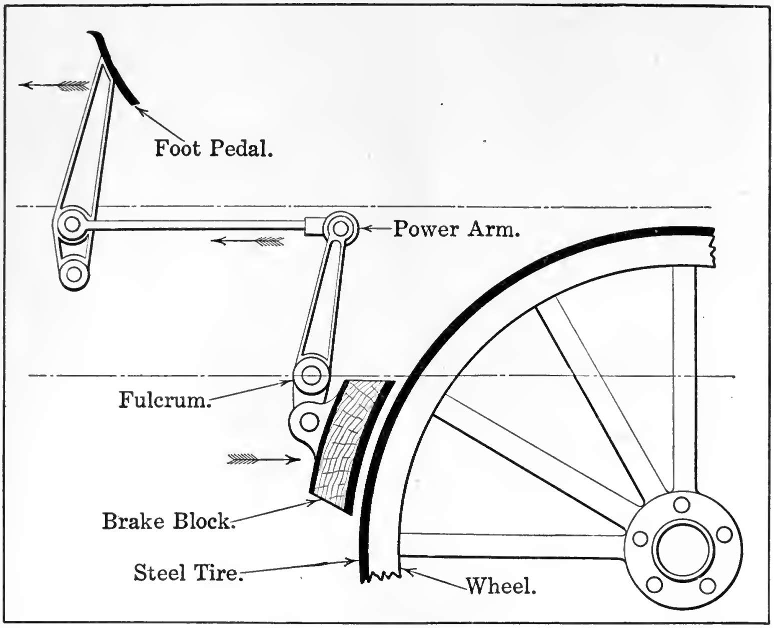


Fig. 297.—Simple Form of Shoe Brake Used on Horse-Drawn Vehicles.

foot pedal will bring the brake block in contact with the periphery of the wheel, and but a very moderate amount of pressure suffices to lock the wheel in a positive manner. This construction could not be very well applied to motor vehicles, because the action of the shoe against the rubber tire would be apt to produce rapid depreciation of these costly elements. For this reason the brakes of automobiles are especially designed so that they will wear instead of producing deterioration of the points to which they are applied.

Forms of Motor-Car Brakes.—The braking members generally used on automobiles may be divided into two classes, each of these depending upon the property of frictional adhesion between substances held together by considerable pressure. The usual construction is to attach a drum to some portion of the change-speed mechanism, to the differential gear or to the wheels themselves. At the present time most engineers favor applying the brakes directly to the driving wheels, and pressed-steel drums are usually fastened to these members, against which the brake acts. The retarding effect may be obtained either by an internal expanding shoe brake or by an external contracting band brake.

The principal forms are outlined at Fig. 298. That at A consists of an internal expanding member consisting of two shoes which

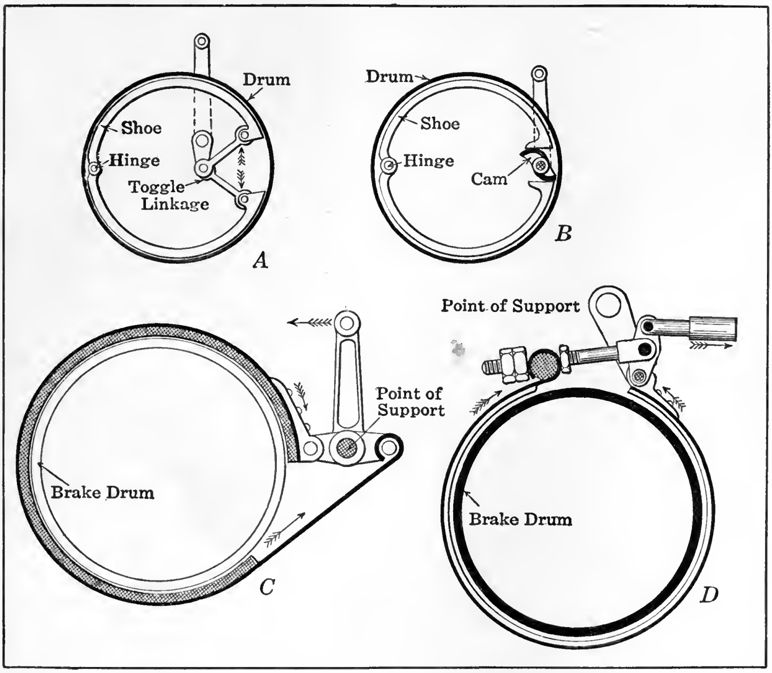


Fig. 298.—Internal and External Band Brakes Used on Motor Car Wheels.

conform to the arc of the brake drums. These are spread apart and brought into forcible contact with the drums by means of a simple lever and toggle linkage. Another method of expanding the internal band so it will engage the inner surface of the drum is outlined at B. In this the toggle linkage is replaced by a cam which is rocked by the lever to force the brake shoes apart when it is moved in one direction, and permits them to close up and release the drum when it is rocked the other way.

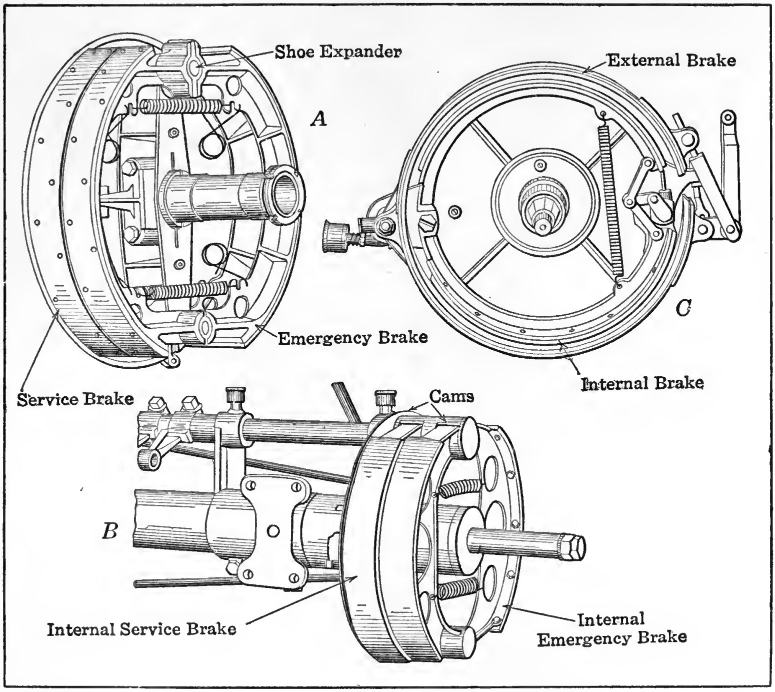


Fig. 299.—Typical Automobile Brake Forms. A—Two Internal Bands. B—Double Expanding Type. C—External and Internal Brake Combination.

The brake shown at C consists of a steel band which is lined with some friction material possessing considerable resistance to heat, such as asbestos-wire fabric. The band is attached to a double-bell crank lever in such a way that it will be brought into forcible engagement with the external surface of the drum if the end of the lever is moved in the direction of the arrow. Another form of band brake is depicted at Fig. 298, D. This is a much more efficient form than that outlined at C and it has great holding power. The band may be adjusted as the friction material wears, and thus the brake may be always kept in perfect adjustment.

The methods in which the brakes are usually mounted in automobiles are clearly shown at Fig. 299. At A two internal expanding bands are mounted inside of each brake drum, one pair of these being connected to a pedal and used as a service brake, while the other is attached to a hand lever and is depended upon as an emergency or

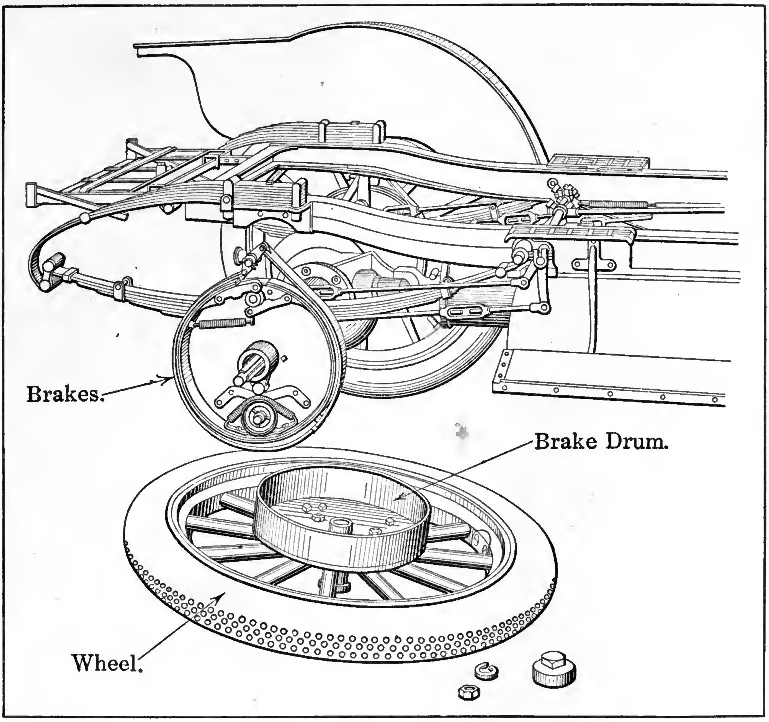


Fig. 300.—Typical Automobile Brake Assembly with Rear Wheel Removed to Show Application of Brake Drum to Wheel and Internal and External Bands on End of Axle.

auxiliary braking member. The cast shoes are hinged at their lower end and are faced with friction material. They are spread by means of cam expanders, and when the shoes are spread apart they engage the inner portion of the brake drums with considerable force and retard its motion. The brakes shown at B are similar in operation to those outlined at A, and the assembly is presented merely to show the relation of the brake shoes to the axle on which they are mounted. A combination of internal expanding and external constricting brakes is shown at Fig. 299, C. This is a very common method of construction and is found on many cars. The inner brakes are usually depended on for emergency service, while the outer brakes, which may be more easily applied, are used for braking under ordinary conditions. A common brake drum serves both brakes, as the expanding member will engage the inner periphery, while the external band will contract around the outer face of the drum. The method of installing the brake on a typical motor-car rear construction is shown at Fig. 300.

The braking members in automobiles have been mounted on both front and rear wheels, on the jack shaft of a double-chain driven car,

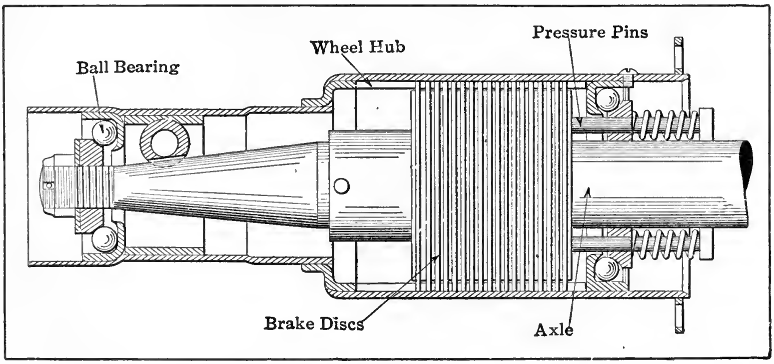


Fig. 301.—Rear Hub of Metz Car Showing Multiple-Disk Brake.

or on the propeller shaft of a bevel- or worm-gear drive arrangement. Brakes are not always of the internal or external band form, some designers having used other combinations to obtain the same results. The multiple-disk brake employed on the Metz car is shown at Fig. 301. In this a series of disks is attached to and revolves with the wheel hub, while another group is fixed to the stationary axle. Pressure is brought to bear against one of the fixed disks by means of pressure pins passing through one of the wheel-supporting cones, and this is in turn communicated by each disk to its neighbor. The same object is attained as in a multiple-disk clutch and a larger amount of braking surface is obtained by using a comparatively large number of small diameter disks instead of two larger members, which might not have as much effective surface. Multiple-disk brakes have been used to some extent on foreign cars, but this is the only instance to the writer's knowledge where they have been applied on a domestic product.

Side slipping or skidding is one of the dangers of motoring on highways which may have a slippery surface. If one turns the corner of a wet asphalt, macadam, or clay pavement a certain amount of side-slipping action will be evident, and if the brake be applied at this time this skidding tendency will be accentuated. The skidding tendency of a self-propelled vehicle is most noticeable when the brakes are applied suddenly to the rear wheels, and it is evident by a swinging movement at the rear end of the car which tends to bring the braking wheels around to the front in the direction in which the car is moving. Various means have been proposed to eliminate this side-slip action, and numerous forms of tire chains, studded tire treads or treads with knobs or other projections of rubber molded integral with them have been devised to minimize the skidding tendency.

Application of Front-Wheel Brakes.—A number of foreign engineers have applied brakes to the front wheels instead of the rear members to reduce the skidding action. It is claimed that the application of brakes to the steering members instead of the driving members will eliminate the skidding tendency, because the braking action would be on the wheels which were already at the front end and pointing in the direction in which the car was moving. There are a number of disadvantages which militate against the general adoption of front-wheel brakes, these being of a nature which makes them extremely difficult to surmount successfully.

In the first place, it is rather difficult to mount the brakes on the steering knuckles and operate them from a fixed portion of the car. Then, again, the usual front axle, as designed at the present time, is not adequate to resist the torsional stresses which obtain when the motion of the car is stopped by arresting the rotation of the front wheel, and some form of torque member would have to be provided to take care of this strain. This would mean considerable mechanical complication which is not necessary, as when the brakes are applied on the rear wheels one common member may be used to take both braking and driving torque stresses, and this member would be needed, even if the brakes were applied to the front wheels, in order to take care of the driving torque.

If brakes are applied to all four wheels, some arrangement must be provided by which the front-wheel brakes could be applied first to do away with the tendency to skidding, while the rear brakes would be called upon to add to the braking effort already provided. The principal difficulty in fitting up front-wheel brakes is in the arrangement of the operating parts. These must be attached to the vehicle frame at one end, and must also be supported on the axle at the other, and as the axle is free to move relative to the frame it will be evident that the problem of providing a flexible and positive braking connection will be made more difficult of solution when one considers that some provision must be made for the angularity of the wheels when turning corners. This would mean that the operating mechanism on one side must shorten, while that at the other side must lengthen in some way to compensate for the difference in angularity of the brake drums. Whatever form of brake actuation is used it must be designed so these members will be applied with equal force and at the same time in each wheel. This problem is not a difficult one when the brakes are attached to the rear axle, but it is not easy to operate front-wheel brakes in a positive manner and insure that each will be applied with equal force.

Various forms of front-wheel brakes are shown at Fig. 302. The design shown at A is a cam-expanded shoe which is mounted on an extension of the steering spindle. The cam is rocked by means of a lever attached to it, which is moved by a pin passing down through the steering knuckle bolt and resting against the end of a bell-crank form of brake lever carried by the axle. When the brake lever is moved the movement of the end against which the pin rests is transmitted to the cam which spreads the shoe by means of the pin passing through the steering knuckle. Another form of cam-expanding brake is outlined at B. In this the cam is rocked by a lever which passes down to the bottom of the steering spindle, where it is coupled to the operating gear by means of a steel-wire cable passing around a roll at the end of the steering-knuckle bolt designed to give a cer-

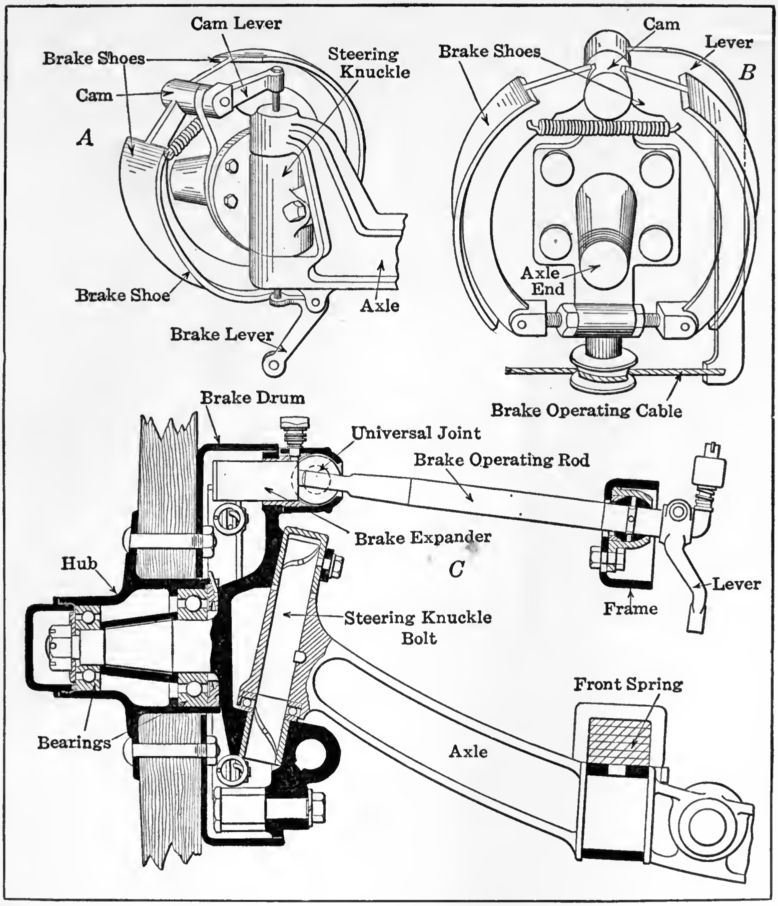


Fig. 302.—Types of Front-Wheel Brakes that Have Been Used on British Automobiles Showing Novel and Ingenious Methods of Brake Actuation.

tain degree of universal motion. The shoes are kept from rubbing against the inner face of the drum by a coil spring joining the upper extremities of the shoes to keep them in contact with the cam face. The brake shoes are supported at the bottom in adjustable yokes which may be moved out to compensate for wear of the brake-shoe surfaces.

The method outlined at C is that used in the Argyl (Scotch) motor car. In this form the brakes are operated directly from the frame side instead of by bell cranks or wire cables attached to the axle. The brake is a cam-expanded shoe type, the cam being moved by a brake-operating rod, extending from the frame-side member to the top of the fixed member employed to carry the brake band which forms part of the steering knuckle. The brake-operating rod is provided with a pair of double ball-and-socket universal joints and is operated by means of a small lever attached directly inside of the frame-side member.

Front-wheel brakes have not been used to any extent on American motor cars, but they have been applied in quite a number of instances abroad. The advantages advanced by the English designers for this peculiar form of brake are chiefly centered around the factor of eliminating skidding and of being more accessible and easier to adjust than the rear-wheel brakes. Against these advantages one may advance the disadvantages of complicated operating mechanism, the possibility of unequal braking effort, and the interference with positive and correct steering should some one of the universal operating rods become stuck in such a way that it would not permit the wheel to turn as it should.

CHAPTER X

Wheels, Rims, and Tires—Wood and Wire Wheels Compared—Resilient or Spring Wheels—Advantages of Pneumatic Tires—Pneumatic Tire Construction Outlined—Forms of Tire Treads—Tire Protectors and Non-Skid Attachments—Demountable Rim Forms—Features of Cushion Tires—Solid Tire Types—Tools and Supplies for Tire Restoration—Faults of Tires and Their Elimination—Apparatus for Tire Repairing.

BEFORE considering the forms of various tires and rims in general use, it will be well to give the subject of wheel construction some consideration. These are a very important element of the motor-car chassis and much of the safety and comfort of the occupants of the vehicle depends upon the proper selection of wheels of sufficient size and adequate strength. At the present time the wood wheel is the most popular form in use in this country, though abroad considerable attention is being paid to the development of wire and metal wheels.

The first form of wheel to be applied to automobiles was patterned after the forms used on bicycles, as it was thought that many of the same engineering principles applied equally well to both forms of conveyances; and as many of the early designers and builders of motor cars were formerly in the bicycle industry, it seems but natural that they should attempt to apply some of the experience gained in that field to the newer one of automobile construction. Wire wheels were soon supplemented by wood wheels of the artillery type, because these were very strong and presented an appearance that was not unconventional because it did not differ very much from the wheels generally used on horse-drawn vehicles.

Characteristics of Wooden Wheels.—Two forms of wooden wheels have been applied to automobile service. The first to be used employed a Sarven type hub which did not prove strong enough, and was later succeeded by the artillery type. The Sarven wheel is the form that is widely used on light carriages and wagons, and in this construction the spokes are forced into suitable holes made to receive them and held in a wooden hub, and the whole assembly of hub, spokes and felloe are held together by shrinking a steel tire around the assembled wheel. This was supplemented by some form of rim adapted to take a rubber tire when used for automobile work. The

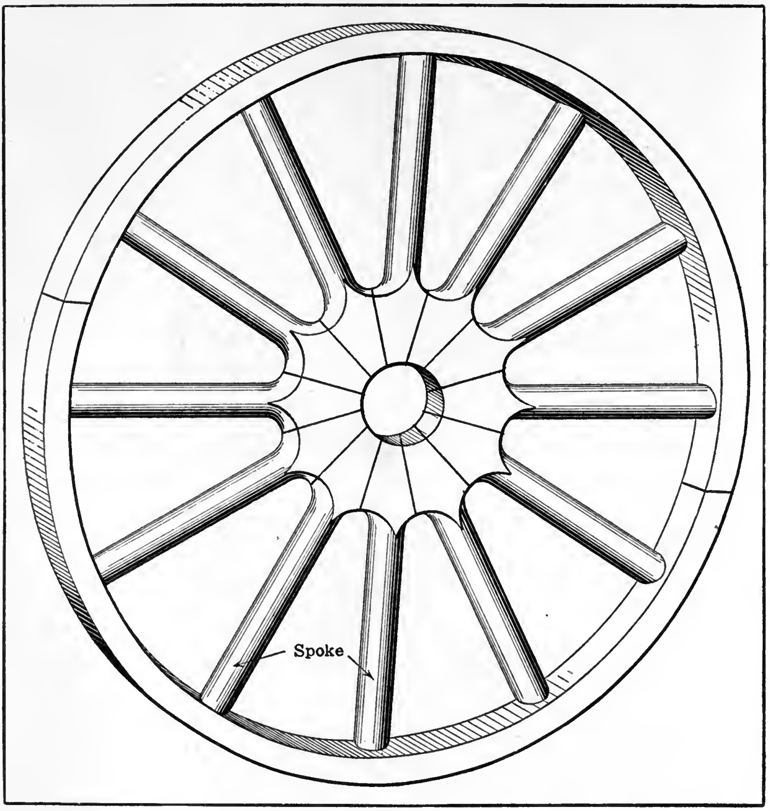


Fig. 303.—Wooden Portions of Artillery Type Automobile Wheel.

Sarven type hub did not prove satisfactory on vehicles of the self-propelling form, except on very light motor buggies where the drive was by side chain to a sprocket attached to the spokes.

Some attempts were made to use this type of wheel on live axles by driving in a metal bushing in which the keyway by which the wheel was secured to the axle was formed. Considerable trouble was experienced by the metal bushings coming loose in the hubs and failing to drive the wheel. Then, again, the Sarven type wheel was not strong enough to stand the side thrusts of the heavier automobiles, and was soon replaced by the form at present used, in which a metal hub forms the center of the spoke and felloe assembly.

The wooden parts of the artillery wheel are depicted at Fig. 303, while the construction of the hub can be very clearly understood by referring to drawings in preceding chapter. The ends of the spokes which fit between the hub flanges are wedge shape and are so formed that they will fit closely together when assembled to produce a complete circle of wood which is sandwiched between the wheel-hub flanges, held together by bolts passing through them and the spokes. The outer end of the spokes is turned down to fit holes bored into the arcs that comprise the felloe. The wheel assembly is held together in much the same manner as that employed in carriage-wheel construction, excepting that the steel rim is usually provided with hook section flanges made to hold the clincher tire generally used. A complete wooden-wheel assembly with hub, demountable clincher rim, and pneumatic tire is shown at Fig. 304.

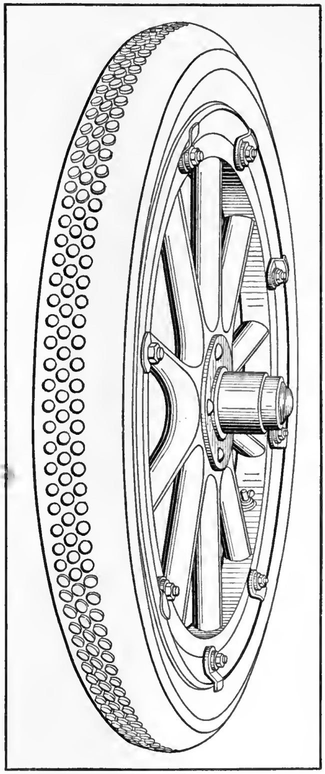


Fig. 304.—Complete Artillery-Wheel Assembly.

Wire and Metal Wheels.—At the present time automobile engineers seem agreed that second-growth hickory is the only wood that can be used successfully in automobile-wheel construction, but it is becoming more difficult to obtain this material as the production of automobiles is increased. In England the wood is very scarce, so many designers in that country are returning to the wire-spoke type of wheel which was used on the earlier model cars. Suitable wood for wheels is not easy to obtain, because it must be of such a nature that it will stand both a steady load and sudden shocks. Hickory alone of all common woods combines these two features, and while other trees may furnish lumber that may be stronger or tougher than hickory, in some applications it is the only one which seems to combine the desired qualities. When the supply of wood decreases to a point where it will be difficult to obtain it promptly, it is believed that automobile manufacturers will be forced to use metal wheels.

This has been done by some of the producers of heavy commercial cars in some instances, and the metal wheels which have been applied may be divided into three types. Those used on the heavier vehicles may be of cast steel, having a spoke and hub construction very similar to that of the present-day artillery wooden wheels, except the hubs and rims are cast integral with the spokes. This forms a very strong wheel assembly; the only objection that can be advanced against them is that while stronger than wooden wheels they are much heavier. Metal wheels are sometimes made by fastening two steel stampings together to form the rim and web portions, these in turn being joined to a separately formed flanged hub member.

The metal wheel most generally used, however, is the suspension type so commonly used in bicycles and motorcycle construction. In this the steel hub member is joined to the outer rim by spokes of steel wire interlaced in such a manner that they hold the hub and rim together firmly. One advantage of metal wheels is that this material may be worked up into any desired form, and, where lightness is desired, one can use wire-spoke wheels and either the built-up pressed-steel forms or the cast-steel wheels for heavy loads. If lightness is desired, light metals which are very strong are available, while maximum strength is obtained by the use of the highly resisting materials in the cast form.

The wire wheel has not attained any degree of popularity in America, but its gradually widening field of use in England and on the Continent shows that it is a big success and that in its improved forms it has much to commend it for automobile service. The wire wheel is lighter than a wooden wheel of equal strength, there being a saving of at least $33\frac{1}{3}$ per cent of weight when wire wheels are employed instead of the artillery type. Advocates of the wire wheel state that it is stronger than the wooden wheel in both vertical and horizontal directions. In a wooden wheel the load is carried on the spokes which are under compression, whereas in a wire wheel the weight is carried by the spokes which are under tension.

A series of tests conducted abroad showed that wire wheels were much stronger and resisted blows of greater definite strength applied to the rim than wooden wheels of equivalent rated capacity. It is also contended that wire wheels are much more elastic and resilient than the wooden supporting members, and that a car equipped with these will be more easy riding and wear the tires less than another chassis of the same weight mounted on wooden wheels. Wire wheels are not used to any extent on heavy vehicles, and when metal wheels are fitted to trucks they are usually of the heavier forms. A typical wire-wheel assembly is shown at Fig. 305, this being a form used to a large extent on touring vehicles in England.

There are a number of disadvantages which militate against the general use of wire wheels, the most serious of these being the fact that when the tension of the spokes is different the wheel will go out of shape and will not run true. No matter how carefully the wheel is built up, the constant shock incidental to service will cause some of the spokes to become loose in the nipples by which they are attached to the rim. When these are tightened up the entire wheel must be gone over to insure that all spokes pull evenly and that the hub is exactly in the center of the wheel after adjustments have been made. It is argued that a wooden wheel that has received a violent side blow will be almost entirely demolished, whereas a wire wheel subjected to a similar shock may be sprung out of true, but will have sufficient strength to allow the motorist to drive the car to some point where the wheel can be repaired.

In connection with this it may be stated that a wooden wheel, if damaged, may be repaired by any blacksmith or wheelwright, whereas a wire wheel can only be restored to its efficient condition by a mechanic skilled in truing up the wheel. Another disadvantage of some moment against the wire wheel is that it is a very difficult form to keep clean, as, when the vehicle is washed, the brightly nickeled spokes must be wiped off carefully or they will rust. This precau

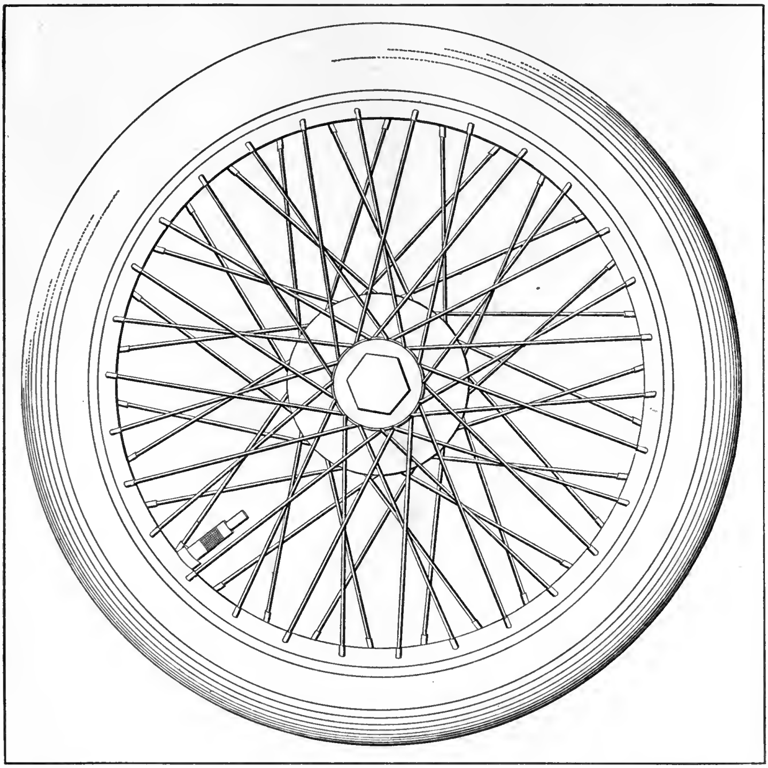


Fig. 305.—Wire-Spoke Automobile Wheel Modified from Bicycle Practice.

tion need not be taken with a wooden wheel, as there is no multiplicity of joints and minute crevices where dirt or water may lodge.

Spring and Resilient Wheels.—Attempts have been made to build wheels which would have some form of flexible or yielding member to join the rim and the hub, instead of the rigid wood or metal spokes. Many spring wheels have been evolved, the ultimate aim of all inventors of this form being to provide a supporting member which would have sufficient resiliency so the pneumatic tire could be dispensed with and the troubles incidental to its use eliminated.

The Lipkowski spring wheel is depicted at Fig. 306, this being a fairly good example of the radial coil-spring form which is said to have given fairly satisfactory results in its trials. In this construction the hub and felloe are composed of two members held together

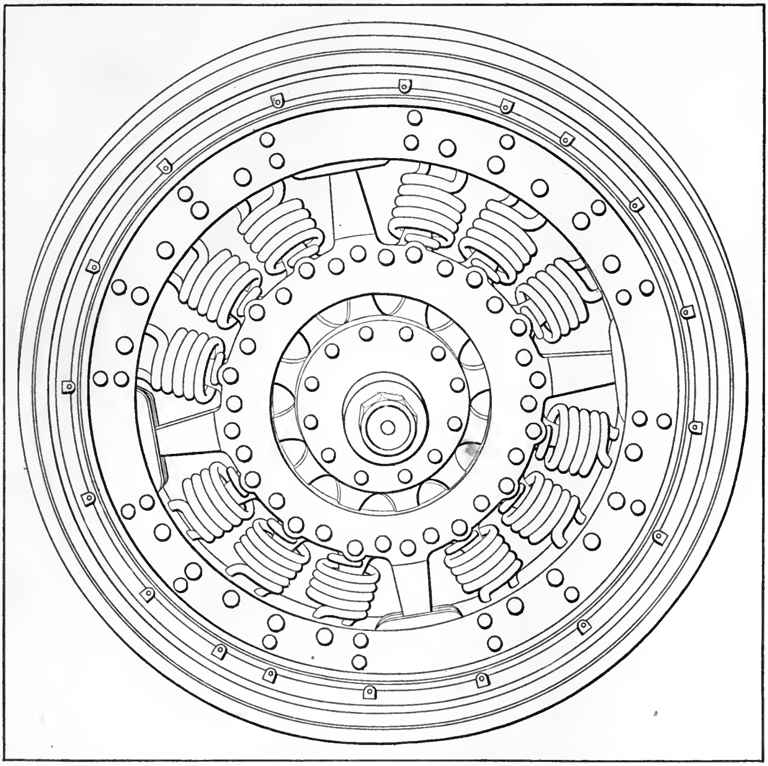


Fig. 306.—Steel Resilient Wheel Having Coil Springs Separating Hub and Rim Members.

by bolts. These retention members form the journals for the loops on the end of the spring, while the spaces between the outer portions of the wheel felloe are a sufficient distance apart to act as a guide for the four solid metal spokes which are spaced ninety degrees apart and which radiate from the outer periphery of the hub member. Twelve springs are used, these being mounted in sets of three, each set occupying the space between the two spokes.

The resilient members are attached in such a manner that they are subjected to alternate compression and tension loads. Those at the top of the wheel are under tension, while those at the lower portion are under compression. The four rigid steel spokes engage suitable projections on the inside of the felloe and are depended on to keep the wheels steady against side blows and to furnish a positive means of driving when the wheel is used as a traction member. The disadvantage of this type of construction is that the springs are liable to break and that the construction is very heavy when compared to wooden wheels. It is claimed that this type of wheel is fifty per cent heavier than an ordinary wooden wheel of greater strength. Another disadvantage of spring wheels of this pattern is that they are apt to be noisy in action, which is not desirable.

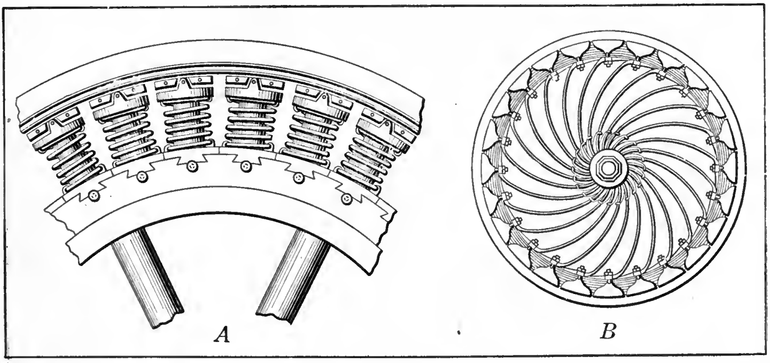


Fig. 307.—Spring Wheels Designed to Provide a Resilient Support for Automobiles without Using Pneumatic Tires.

Two other forms of spring wheels are shown at Fig. 307. That at A employs a series of radial compression springs which provide the resilient feature, while the strength is obtained by means of the plungers fastened to the upper member which is attached to the wheel rim; these in turn fit the cylinders attached to the outer periphery of the inner wheel. The spring serves to keep these members separated at all times. In the construction outlined at B the spokes are flat springs, curved in a peculiar manner, and join the central hub member with the outer rim. Neither one of the forms shown have been adapted practically, and the illustrations are presented merely to show freak constructions which have but little practical value.

It may be said of all forms of spring wheels that their disadvantages are of sufficient magnitude to make those which are advanced against the pneumatic tire seem simple by comparison. While pneumatic tires may fail on the road, they may be easily restored or repaired and the journey continued with but little interruption. If members of a spring or resilient wheel should fail in service the work of replacement would entail a degree of mechanical skill not usually possessed by the average motorist. Many inventors have given this problem considerable attention, but it is safe to say that the rubber tire in either of its forms is absolutely necessary to successful motor-vehicle operation, and that there is but little future for resilient wheels depending on springs or other metal resilient members to cushion the shocks met with when traveling over ordinary highways.

Forms of Automobile Tires.—The wheels of automobiles, with but few exceptions, are provided with rubber tires. The simplest is a solid band of rubber composition; next in order we have the various forms of cushion tires in which the band of rubber is perforated with a number of small holes or provided with a series of openings designed to provide greater resiliency and make the tire more yielding than the solid-rubber form. Solid tires are invariably adapted to industrial conveyances.

The most common form of tire, and that generally used on automobiles, is composed of a hollow rubber tube of circular section filled with air and protected from wear by means of an outer shoe or casing. The use of air under compression provides a very resilient medium for supporting the vehicle, and of the various forms of rubber tires the pneumatic form is the one that is the most desirable. The development of the modern automobile may be attributed largely to the advances made in pneumatic-tire construction, as these members made it possible to drive automobiles at high speed over rough road surfaces without stressing the mechanism or causing discomfort of the passengers. While solid-rubber tires and members of the cushion form have a certain degree of elasticity, they do not ride as easy as pneumatic tires, because rubber cannot be compressed, but only distorted. Solid-rubber and cushion tires are suitable where vehicle speeds are low, but are very unsatisfactory for automobiles traveling at speeds over fifteen miles per hour.

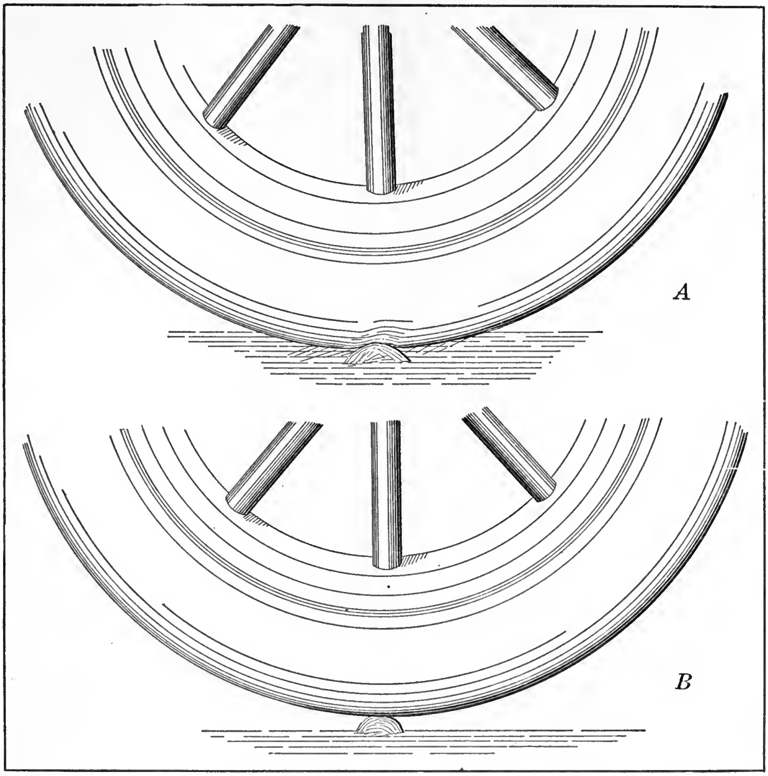


Fig. 308.—Comparison of Action of Pneumatic and Solid-Rubber Tires when Wheel Rides Over Obstacle.

A comparison between the action of pneumatic and solid-rubber tires is made at Fig. 308 so the superiority of the latter form may be readily understood. At A, a wheel shod with a pneumatic tire is shown in contact with an obstacle in the road. When the wheel passes over this obstruction, the walls of the tire, which are relatively light, will deflect inward and compress the air inside of the tires. The wheel is not raised from the ground and the vehicle rides over the obstruction without any appreciable upward movement or throw of the chassis. At B a solid rubber tire is shown passing over the same obstacle. In this case the composition is so stiff that it will not bend in and the wheel is raised from the ground. This throws the vehicle body upward, jarring both mechanism and passengers. The severity of the jolt augments proportionately to the speed of the vehicle. It will be patent that the form of tire depicted at A, which permits the stone to imbed itself into the tire, will be much more easy riding than that form which will ride over the obstacle. The great advantage of a pneumatic tire is that it will give more than ordinary elasticity to the wheel and will absorb most of the minor shocks that would be transmitted to the springs of the vehicle if noncompressible tires were used.

Construction of Pneumatic Tires Defined.—The pneumatic tire of the present day is invariably of the double-tube type and is composed of two members, the inner tube and the shoe or carcass. The inner member is utilized to retain the air and is made of a very pure rubber, about an eighth of an inch thick for cars of average weight. While this tube is very elastic and is air-tight, it would not be strong enough or have adequate resistance to be run directly in contact with the road surface; therefore it is necessary to protect it by a shoe composed of layers of fabric and rubber composition. The shoe member is provided with beads on its inner periphery designed to interlock with the rim channel, as shown at Fig. 309.

The main portion of the outer casing is composed of five or more layers of a Sea Island cotton fabric "frictioned" with high-grade rubber composition. This is forced into the mesh of the cloth by machinery so the fabric will be practically waterproof and will join intimately with the other plies by a process of vulcanization when the shoe is cured. Outside of the fabric body a layer of very resilient rubber, approximately of crescent form, known as the padding, is provided to give a certain degree of elasticity to the shoe. Between this member and the tread a number of pieces of heavy fabric called "breaker strips" are interposed to offer a certain degree of resistance

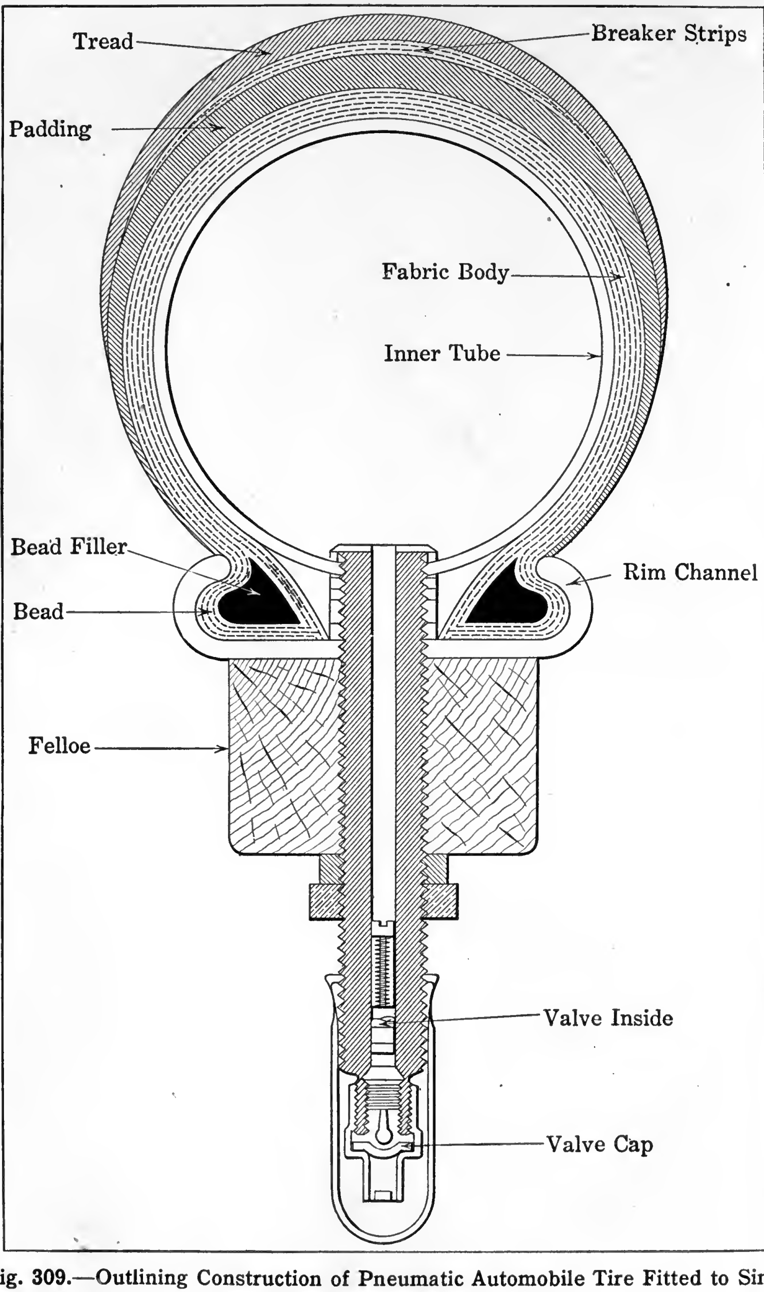


Fig. 309.—Outlining Construction of Pneumatic Automobile Tire Fitted to Simple Clincher Rim.

to any sharp object that might penetrate the tread and go through the padding and into the fabric body if the breaker strips were not interposed to deflect the puncturing object to one side.

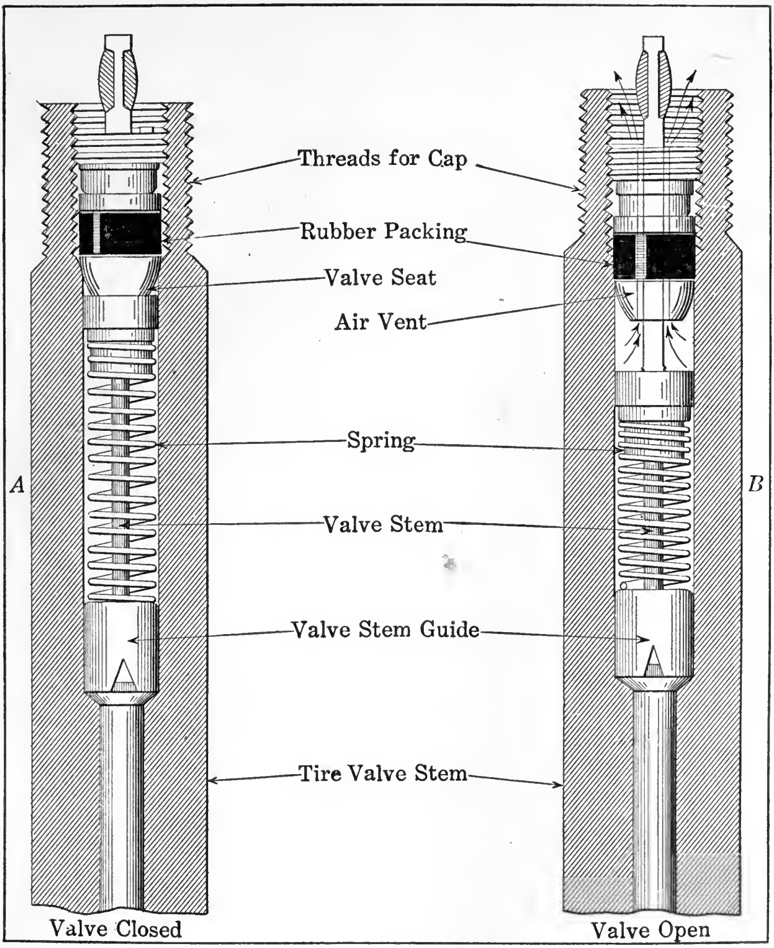


Fig. 310.—Construction of Schrader Universal Tire Valve.

The tread is the part of the tire that is subjected to the greatest stress, as it must resist the abrading influence of the road and, when the tire is used on the rear wheels, the wearing effect of the friction produced by the tractive effort which exists at the point of contact between the driving member and the ground. The tread is of very tough rubber composition and differs from the material used as padding or for the inner tube in that it does not possess a very great degree of elasticity. This quality is sacrificed for that of greater strength and resistance to wear, which is more essential at this point.

The air is introduced into the tire through a simple form of automatic valve which is securely attached to the inner tube. As the inner tube becomes distended by the air pumped into it, it forces the beads of the tire outward and clinches the shoe so firmly in the rim channel that it will be impossible to dislodge it without the use of special tire irons, and then only when the air pressure is relieved from the inner tube. A detailed view of the valve stem in the open and closed position is shown at Fig. 310, and the construction of this simple fitting can be easily understood. The valve is held against its seat by a tension spring and will only open when the valve stem is depressed by the hand or from the pressure of the air forced against it when it is desired to inflate the tire. While the air pressure from the pump will be sufficient to force the valve from its seat, the air pressure from the inside of the tire only serves to hold it more firmly in place.

Pneumatic tires are not always of the clincher form. Various other constructions have been devised, some to facilitate a more ready removal than the clincher construction permits, while others have been designed to make for a more secure attachment by some mechanical means. Various forms of quick-detachable rims and the tires adapted for use with them are shown at Fig. 311. In the ordinary clincher tire it is necessary to force the bead over the channel when it is desired to remove the outer casing, and while this can be accomplished with comparative ease on the smaller tires, it is very difficult to remove or apply large clincher tires. In the form shown at A the clincher rim is made in two parts, one of the sections being easily removable when the locking ring is taken out of the groove in which it fits. When the movable section of the rim is taken off the outer casing may be easily removed, as it can be slipped off the fixed portion of the rim just as a belt can be removed from a pulley.

The Dunlop type of outer casing is depicted at B and C, these also being fitted to quick-detachable rims. In the Dunlop casing

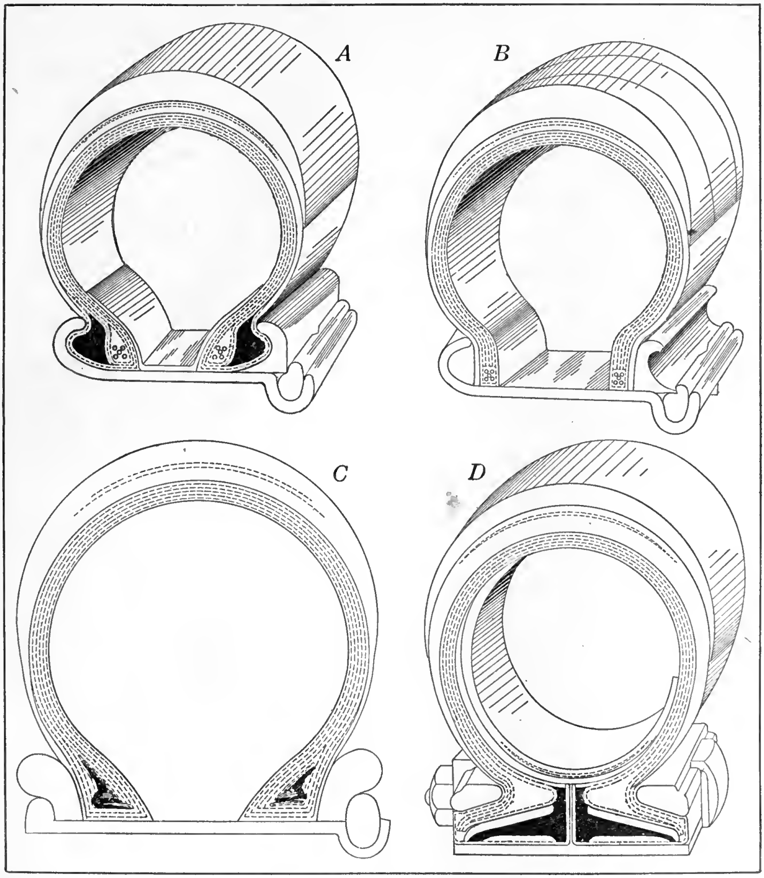


Fig. 311.—Forms of Quick-Detachable Rims which Permit Easy Removal of Pneumatic Tires.

retention is by a series of steel wires at the base of the tire which have a certain amount of holding power, which is further augmented by the air pressure inside of the tube. It is claimed for this construction that it is more easily removed than the clincher tire when applied to a one-piece rim, though on the quick-detachable type shown in illustration one form is as easily removed as the other. The rim shown at A and B is the same member, and it will take either clincher or Dunlop type casing. When used for the latter a rubber filler ring is provided to fill the channel of the fixed portion of the rim, while the flat side of the removable portion is brought in contact with the casing walls instead of the channel or hooked side. The form shown at C is made exclusively for use with Dunlop type casings, and cannot be utilized for clincher tires.

At D the Fisk bolted-on casing is shown. This differs from the other forms in that the clinchers are designed in such a manner that they practically form a foot or base, and when closed together will keep the inner tube away from the rim, which is not done with the other forms of rims. The rim proper consists of a flat band of steel attached to the wheel felloe. Two locking rings are provided, one at either side of the tire, and these are held into proper relation and clamped tightly against the base member of the shoe by means of bolts which pass through the enlarged beads of the casing. This form of attachment is very secure and the tire is held to the rim by mechanical means as well as air pressure. In other forms of tires in which air pressure alone is depended upon to keep the beads in contact with the rim it is possible for tires to be thrown off the wheels if they become deflated, though with the mechanically fastened form, as shown at D, the tire will be held in place, even when partially deflated, much more securely than in the other forms.

The construction of inner tubes is practically the same in all standard makes of tires, and these are usually interchangeable. The outer casings differ in some respects, these being merely a matter of detail involving the number of plies of fabric, the thickness of the padding, the arrangement of breaker strips, and the character of the tread. All the tires shown at Fig. 311 have the plain round tread, which is the most satisfactory for all-around use. The smooth tread, however, has the disadvantage in that it is liable to slip on muddy roads, and for this reason a number of tread forms have been designed to secure greater adhesion to the road or to reduce wear.

A round-tread tire will wear off until the breaker strips are exposed, and the tire should be retreaded as soon as this condition is apparent.

The casings shown at Fig. 312 are a few of the forms which have been designed to secure greater wear of the tread. In that shown at A the tread is raised at five portions and is very thick. In that shown at B the tread is provided with a large number of small

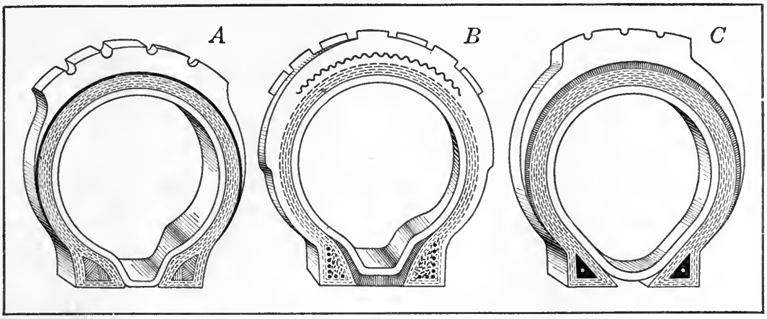


Fig. 312.—Showing Various Raised Treads Used on Pneumatic Tire Casings.

rubber studs or projections which are depended on to prevent side slip more than providing any great amount of added wear to the tread. The form shown at C is known as a raised-tread type, and in this the round tread is reënforced with a flat band running around the outer periphery, this providing a greater thickness of tread than will be possible with the round-tread construction.

The leading forms of treads designed to secure greater traction than that obtained from the plain-tread forms are shown at Fig. 313. In the Morgan & Wright, shown at A, a large number of knobs are molded integral with the tread to prevent skidding. The Empire casing shown at B has a number of disks composed of strips of fabric rolled up and set edgewise in the tread to promote adhesion. In the Swinhart, which is depicted at C, strips of rubber are molded with the tread to form a species of basket weave. This prevents skidding, because the spaces between the strips will fill with mud or dirt and will not slip over the road surface as readily as a smooth tread. The casing shown at D is provided with a number of rings molded with the tread to form little cups which grip the road by the suction effect of the air compressed between the tire and the road surface in the depressions. The Ajax nonskid tread depicted at E is composed of diamond-shaped rubber pieces molded integral with the tread when the tire is cured. A very ingenious method of roughening the surface of the tread to promote traction is that used on the Firestone casings. In this the words "Firestone" and "Non-Skid" are molded in bold lettering alternately and at an angle all around the shoe.

The Harford Midgeley tread is depicted at G. This construction has a series of coil springs molded around the outer periphery of the casing. The Diamond casing outlined at H utilizes the Bailey rubber-stud tread, one of the first antiskidding treads to be devised. In the Michelin casing illustrated at I, a leather band provided with steel studs, which are riveted through it and the casing, is depended on to prevent skidding, to secure improved traction, and to make the casing practically puncture proof from ordinary road obstacles. The Republic Staggard tread tire is shown at J. The principle of providing a large number of projections which is used in the forms depicted at A, D, H, I, is followed on this casing as well, but these knobs are of such size the liability of rapid wear, which is present when rubber buttons of comparatively small size are used, is reduced and the life and antiskidding properties of the tread are augmented proportionately.

While the nonskidding forms of tires have peculiar advantages which adapt them for use on soft and slippery roads, they are more expensive than the round-tread casings, and are really not needed a large part of the time. The labor of changing from the antiskid type of tread to smooth casings would be considerable, and it would not be practical to make the changes as often as conditions imposed by our variable climate would make necessary. For this reason a number of auxiliary treads and nonskid devices have been placed on the market, the idea being to use these in conjunction with the plain-tread tires when necessary. These auxiliaries may be divided into two classes. First, those designed merely to promote better tractive effort and eliminate skidding, and, secondly, those which have been designed to act as a protector for the casing of rubber which they encircle.

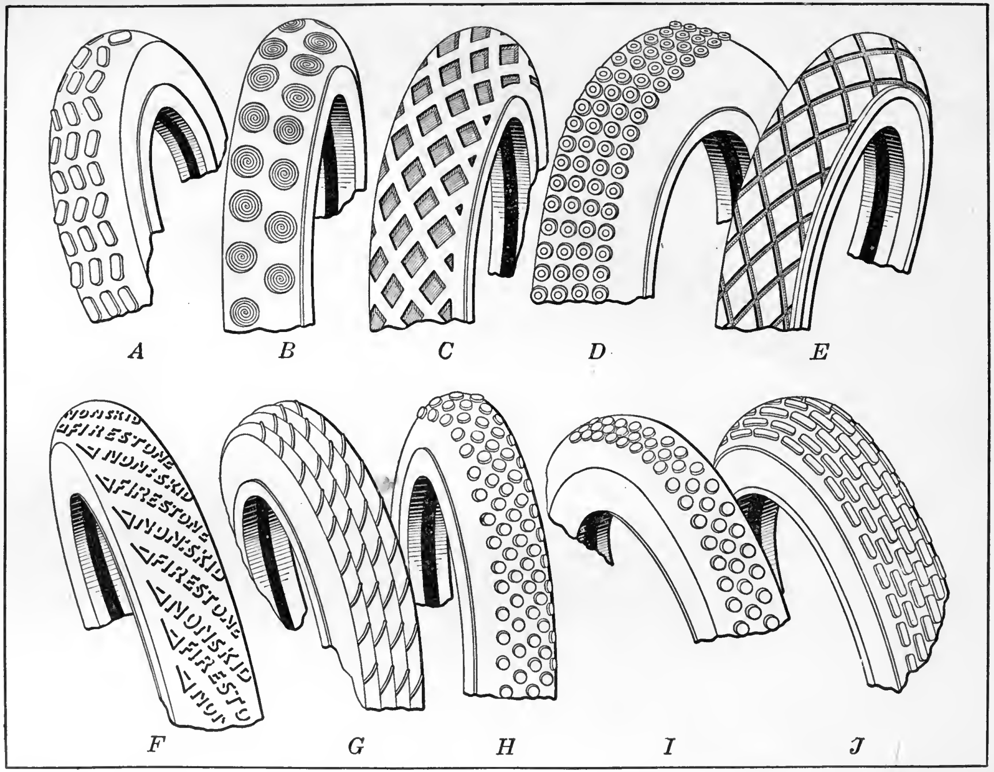


Fig. 313.—How Outer Casing Treads May be Formed to Secure Greater Tractive Effort than Obtained from Smooth Treads and Prevent Side Slipping.

A number of these auxiliaries are shown at Fig. 314. That at A is a leather tread provided with steel studs on the tread surface, made in such a form that it is put around the tire when the casing is deflated and held firmly in place by blowing up the tire again. This may be classed with the tire protectors, as it is believed the heavy chrome-leather band has much more resistance to nails or other objects which might puncture the rubber tube, than the plain round-tread tire would have. At B and C devices which belong to the first class are depicted. These consist of cross chains attached to suitable side members which encircle the wheels. The object of the chains on the tire tread is to eliminate loss-power effort by providing a better grip between the wheels and road surface, and not to act as a protector for the outer casing except in a somewhat limited way. In the form shown at B the cross chains are attached in such a manner that they lie in the same plane as do the rungs of a ladder. At C the chain members are of zigzag form. The protectors shown at D, E, and F are very similar in principle to that outlined at A, except that the method of securing them to the wheel varies to a slight extent. That at D is a form designed to encircle the casing and can be held in place by the air pressure inside of the tire. At E the protector is fastened to the wheel by a series of strap members which clinch under a side-retaining ring member. At F the edges of the protector are provided with hooks which grip the flanges of the clincher tire and thus hold the protector very firmly in place when the tire is properly inflated and the casing distended.

The disadvantage of tire protectors is that they decrease the resiliency of the tire, because leather is not as flexible as rubber, especially after it has become hard by exposure to water. The use of these protectors undoubtedly conserves the tire casing from puncture, but considerable heat is generated between the tire and the protector, and this may be sufficiently high to weaken the rubber casing. Most motorists favor the use of the quick-detachable chains to prevent skidding, because these may be easily removed when they are not needed. There is some labor involved in removing and replacing the leather protectors, and these are not usually used with new casings on account of the decrease of tire resiliency. They are often applied to weak casings or shoes which have been worn to the

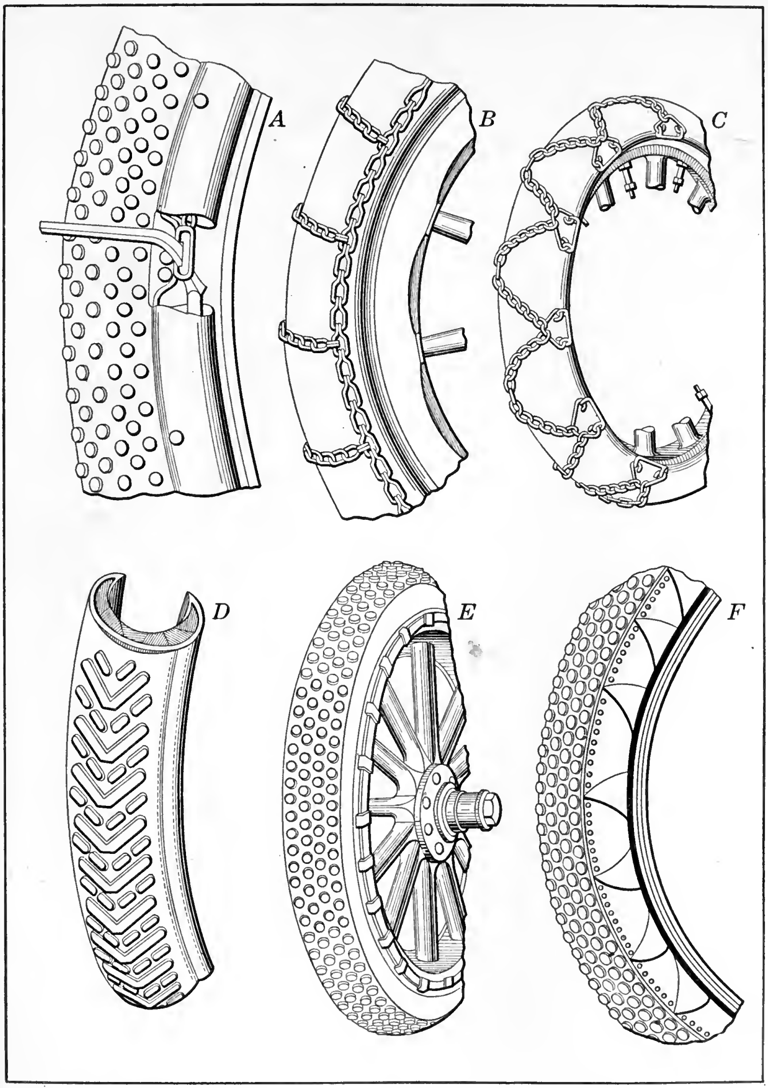


Fig. 314.—Supplementary Treads and Anti-Skidding Attachments Designed to Use in Connection with Smooth-Tread Casings.

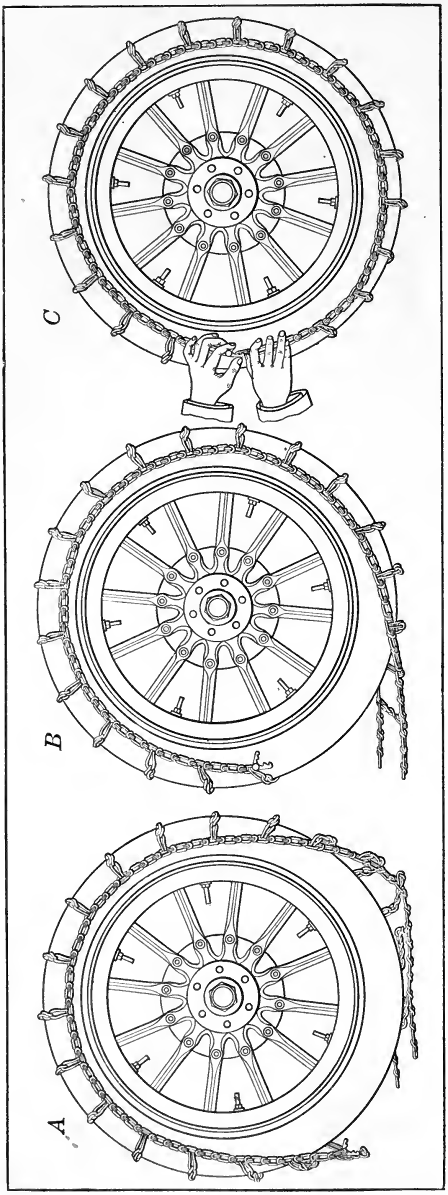


Fig. 315.—Methods of Applying Weed Chains to Tire without Jacking Up Wheel.

fabric, and when used in this manner they are very useful in securing greater service from the weak tires, which would have to be discarded if some form of protecting tread was not used.

The views at Fig. 315 show the ease with which Weed chain grips can be attached to the wheel. In the view shown at A the chain has been applied to the tire and the vehicle has been pushed forward just enough to ride over the loose ends of the chain, which are on the ground. At B the car has been pushed forward sufficiently so the loose ends of the chain are clear of the wheel, and the process of hooking up by means of little snap hooks is easily performed, as outlined at C.

Demountable Rim Forms.—The advantages of the quick-detachable rim over the ordinary clincher pattern have been previously considered. It will be seen that it is possible to remove a tire with less difficulty than is present when the clincher rims are used. While a defective tire may be removed and replaced with a new one very easily, it is necessary to inflate the new tire with air by means of a hand or power pump or with carbonic-acid gas carried under pressure in a portable gas tank. In order to reduce the time occupied in changing tires, which is needed to adjust the shoe properly and blow up the inner tube, a number of demountable rims have been devised. The wheel felloe carries a metal rim, and to this is attached a second member on which the tire is mounted. The tire-carrying rim may be securely attached to the wheel by means of suitable and quickly operated clamping bolts or rims.

When demountable rims are fitted instead of carrying the usual spare outer casing, fully inflated tires are carried on rims similar to the demountable portions, and when the tire is punctured the damaged one and its rim are removed as a unit and a new, fully inflated member replaced. When it is necessary to remove the shoe, as in the ordinary single-rim construction, the operation of replacing a tire will take from ten to fifteen minutes under favorable conditions, but with quick-demountable rims the operation of changing a tire will take only two or three minutes. Demountable rims are more expensive than the simpler forms, but the convenience and elimination of time-consuming delay, as well as the saving in labor, more than compensates for the increased cost of equipment.

Numerous forms of demountable rims have been devised, but few have survived the test of time and have received general application. At Fig. 316 a combination of quick-detachable and demountable rims is shown. With this construction the advantages of both types are obtained without disadvantages of any moment, excepting those of cost of equipment. The quick-detachable type of rim makes it possible to change the tires very easily, should this be necessary, and makes for more easy removal for repairing when the damaged tires are restored to their efficient condition. In this form the tire-carrying rim is held on the felloe band by a clamping collar mounted on the stud and forced in place by a nut on the outer end of the stud. The construction is so clearly shown that its advantages will be readily understood.

The clincher type of rim has been used on many cars because it has been a standard fitting for a number of years, but at the present time it is seldom used in connection with large tires, which are difficult to remove from the wheels unless used in combination with a demountable rim. A number of standard demountable rims which have received general application are shown at Fig. 317. That at A holds the clincher rim which carries the tire in place by a series of clamps and wedges which are forced against the tire-carrying rim

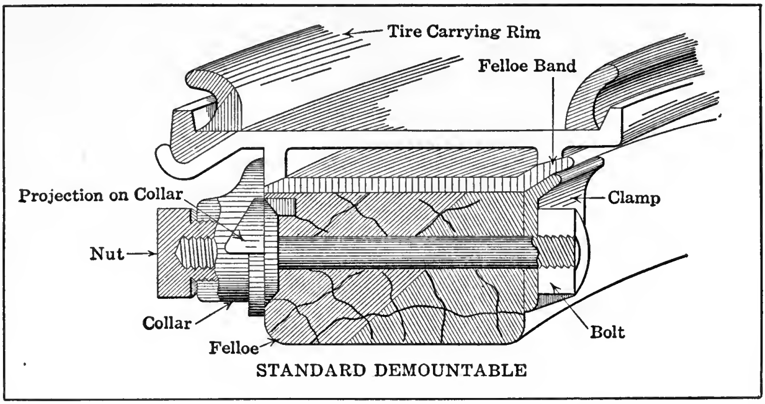


Fig. 316.—Quick-Detachable Rim of the Demountable Form.

by pressure of nuts carried at the end of bolts passing through the wheel felloe and having peculiarly shaped heads, which prevent the tire-carrying rim from moving over the inner edge of the wheel. A number of these bolts are provided, the spacing varying with the weight of car and size of tire. On light cars one bolt to every two spokes is considered ample, while on heavier vehicles a bolt may be used between every two spokes, which would mean that there would be as many clamping bolts used as there were spokes in the wheel.

The form outlined at B is similar in construction to that outlined at A, except that the felloe band is a substantial member which does not need to be reënforced to hold the tire-carrying clincher rim firmly in place when the clamps are screwed home by the nuts. The Fisk demountable rim, used in connection with the Fisk bolted-on type of detachable tire, as shown at Fig. 311, D, is outlined in section at Fig. 317, C. In this a portion of the felloe is chamfered off and

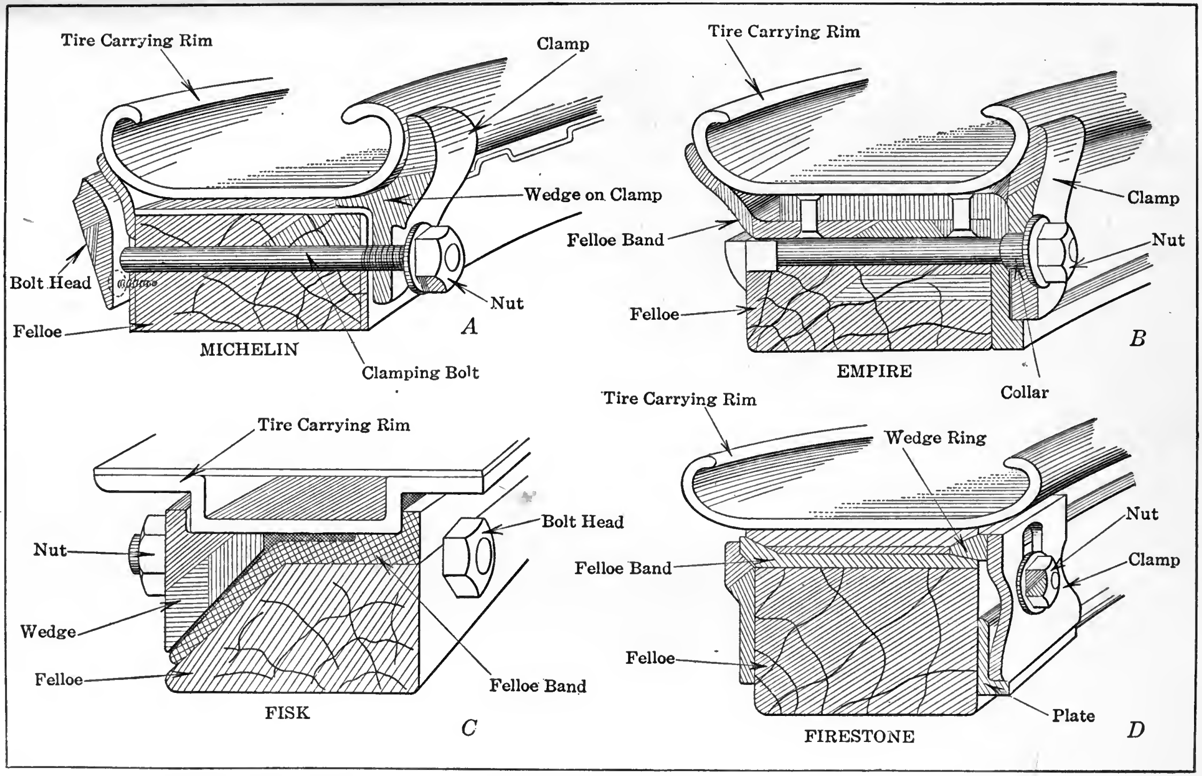


Fig. 317.—Examples of Standard Demountable Rims for Conventional Types of Casings.

the felloe band is made to fit. The tire-carrying rim is locked in place by a wedge member that slides on the angular side of the felloe band when pressure is brought to bear upon its face by the nuts carried at the end of the bolts passing through the felloe and felloe band. As the wedge rides up on the incline it locks the tire-carrying rim firmly in place and prevents either lateral or circumferential displacement.

In the construction depicted at D a tire-carrying rim of the clincher type is used, and this in turn is attached to a ring member which has chamfered corners. The felloe band has two inclines, one designed to rest against one side of the chamfered ring, while the other acts as a seat for the wedge-shape locking ring, which is forced in place under the tire-carrying rim by means of clamps and nuts. In order to make for quick removal, a wrench of the socket type is usually attached to a bit brace, such as used by carpenters, for loosening and tightening and clamping nuts. With some forms of demountable rim it is necessary to remove the nut entirely in order to slip the clamp off the bolt. In others the nuts are merely loosened and the clamps either swung or dropped out of the way of the tire-carrying rim, which is easily slid off the felloe band. Other forms of demountable rims have been devised in which the tire-carrying member is held in place by some form of expanding bands which is made to increase its diameter by means of wedges or cam action, but these are not so generally used as the types described.

Features of Cushion Tires.—Some classes of vehicles that are not designed to run at high rates of speed, and which are not intended to carry heavy loads, are fitted with cushion tires. While these do not have the resiliency of the pneumatic form, they have much greater flexibility than solid-rubber tires. For this reason they are sometimes used on the electrically propelled light delivery or pleasure vehicles and sometimes on the light-weight commercial cars of the gasoline type. Some of the popular forms of cushion tires are shown at Fig. 318. At A the tire tread, which is of the dual form, is molded in such a manner that a series of shallow grooves are formed around the tire. These incline from the outside toward the center and are depended on to give improved traction as well as to make the tire more resilient. The base of the tire is pierced with a large number of holes which extend clear through from side to side, so the outer tread or load-carrying portion is supported on a series of rubber bridges which are adapted to bend and provide a certain degree of flexibility.

The cushion tire shown at B is similar in form to the conventional clincher casing, and is designed to be used on clincher rims

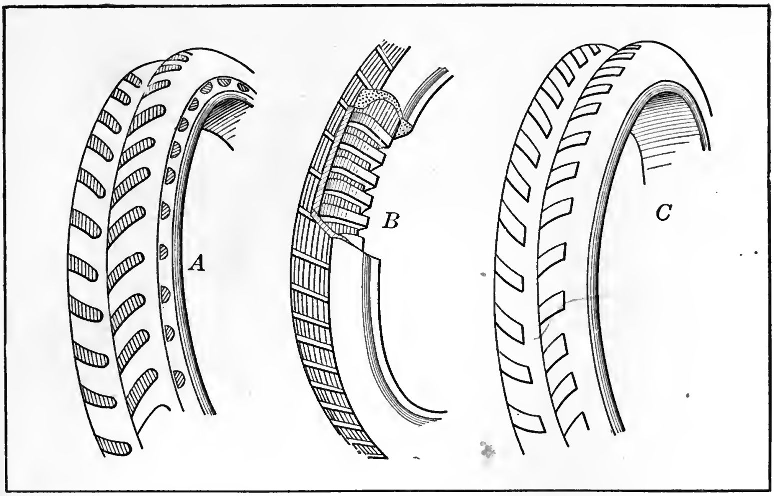


Fig. 318.—Cushion Tires which Provide More Resiliency than Solid-Rubber Types but are Not Equal to the Pneumatic Forms.

of the pattern commonly supplied with pneumatic tires. The flexible feature of this tire is obtained by using a number of rubber load-supporting partitions to join the walls of the tire, and at the same time they are separated from each other by an air space of sufficient size so the tire will distort more easily than the conventional solid-rubber pattern. The cushion tire shown at C depends upon the form of tread to provide resiliency, and it would not be as flexible as either of the two forms previously considered.

One objection to either solid or cushion tires is that a deep cut or stone bruise will seriously weaken the entire structure, whereas only a limited portion is really unfit for use. Then again, sometimes, when brakes are locked too suddenly, a portion of the tire may be worn more than the other parts, but the entire efficiency of the tire will be affected and the strength will depend upon that of the weakest portion. The sectional cushion tire which is depicted at Fig. 319, A, has been evolved to make possible the replacement of one or more injured portions without disturbing the other members. The tire is composed of a series of hollow rubber segments, as shown, which

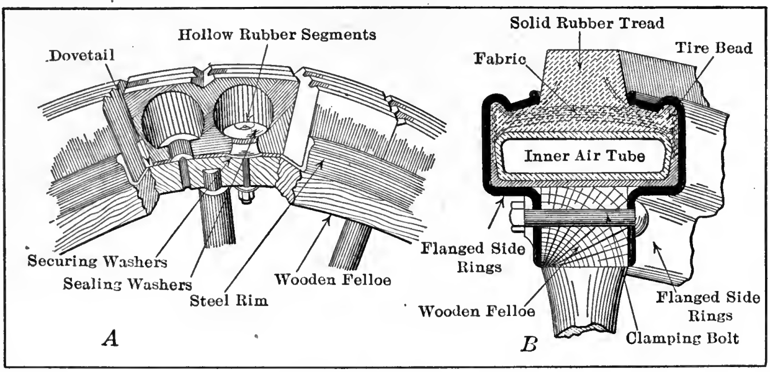


Fig. 319.—Novel Forms of Cushion Tires. A—Cairns Detachable Segment Construction. B—Combination Form Comprising Heavy Tread and Inflatable Inner Tube.

are held securely in place by means of a dovetail structure which extends from the face of one segment to engage with a corresponding member on one of the faces of the neighboring segment. These are securely fastened to the wooden felloe of the wheel and into the steel rim by means of bolts and washers. A certain amount of air is retained in the spherical chambers of the rubber segment by the sealing effect of a special washer, and this provides an air cushion which makes for easier riding than would be possible with a solid tire. In event of damage to one segment it may be removed without difficulty and a new one substituted.

A combination cushion tire composed of a heavy solid-rubber tread and an inner tube inflated with air to form a cushion is shown at Fig. 319, B. It is claimed for this construction that the resiliency is not greatly diminished and that the tire is absolutely puncture proof. The tire consists of two main parts, the solid-rubber outer tread being of rubber composition and mounted on a base of fabric and rubber, and the air tube, which is inflated and which provides the resilient effect. Both members are firmly clamped between circumferential steel flange side rings. The inner tube rests upon an ordinary steel rim or bonding member attached to the felloe, which is made wider than the usual construction and of channel form. The steel flanges are extended beyond the rim and are turned over at their outer edge in such a way that they form grooves to hold the beads of the tire, and continue to the base of rubber tread, where they end in a bead and leave sufficient space between them for the solid tread to work up and down. One of the flanges is permanently fastened to the felloe, while the other is removable by unscrewing the clamping nuts.

It is claimed that as the flanges enclose the air tube as well as the weaker portions of the outer member which are subjected to the air pressure, a very strong construction is obtained. The solid-rubber tread is the only portion that comes in contact with the road, and provision is made to prevent the air tubes being chafed by the sides of the steel rim or by the edges of the outer member. When the solid tread encounters an obstacle in the road it is pressed inward against the air tube in the same manner as the conventional form of outer shoe is, and more resiliency is obtained than with the rigid solid form. The inner tube is well protected from puncture, and it is also claimed that blow-outs are almost impossible, because to reach the inner tube it would be necessary to pierce either the heavy solid tread or one of the steel side flanges.

Forms of Solid-Rubber Tires.—On heavy commercial vehicles it is not practical to use pneumatic tires because these would have to be of very large size to carry the loads imposed by the usual heavy truck chassis and loaded body. As the speeds of these vehicles are not very high, solid-rubber tires may be employed to advantage. These are molded from special rubber compositions in one continuous ring, and they are usually provided with some form of metal reënforcement at the bottom which insures that they will clamp tightly against the rim or the felloe band. Various forms of quick-detachable rims have been evolved to hold these members in place, and the metal reënforcements at the bottom vary from simple transverse wires to continuous bands of steel molded integral at the base of the rubber rings.

A number of solid tires and methods of attachment are clearly shown at Fig. 320. Single tires of this form are used on the front wheels of practically all trucks, though the rear members are generally supplied with dual tires, which have greater carrying capacity and which also lessen the dangers of side slip on wet pavements.

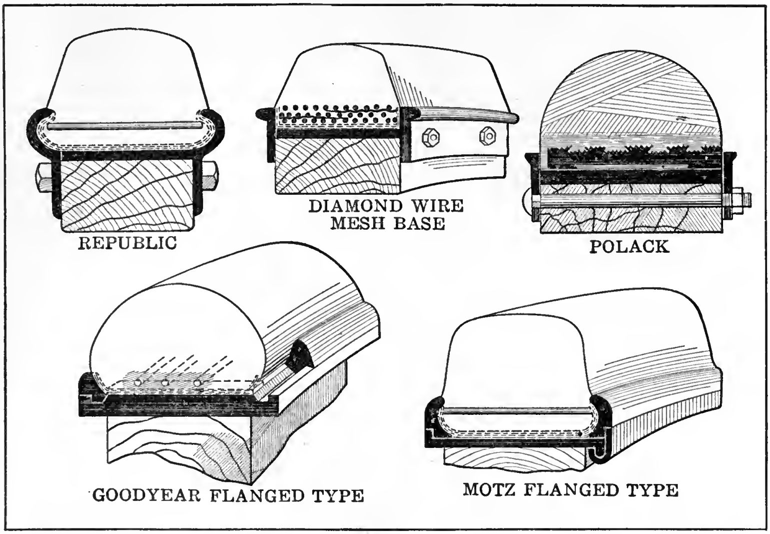


Fig. 320.—Outlining Construction and Methods of Fastening Solid-Rubber Tires to Wheels.

When twin tires are used it is desirable that they be installed in such a way that they can be readily removed from the wheel for replacement in event of wear, and it is also thought necessary to provide means of attachment of such nature that they can be removed independently, if desired. Various dual tire forms and the method of holding them in place are shown at Fig. 321. The construction outlined at Fig. 322 shows the application of wedges to lock the solid-rubber tires firmly to the wheel.

When solid-rubber tires were first applied to trucks they were of such form that special machinery was needed to install them, and the

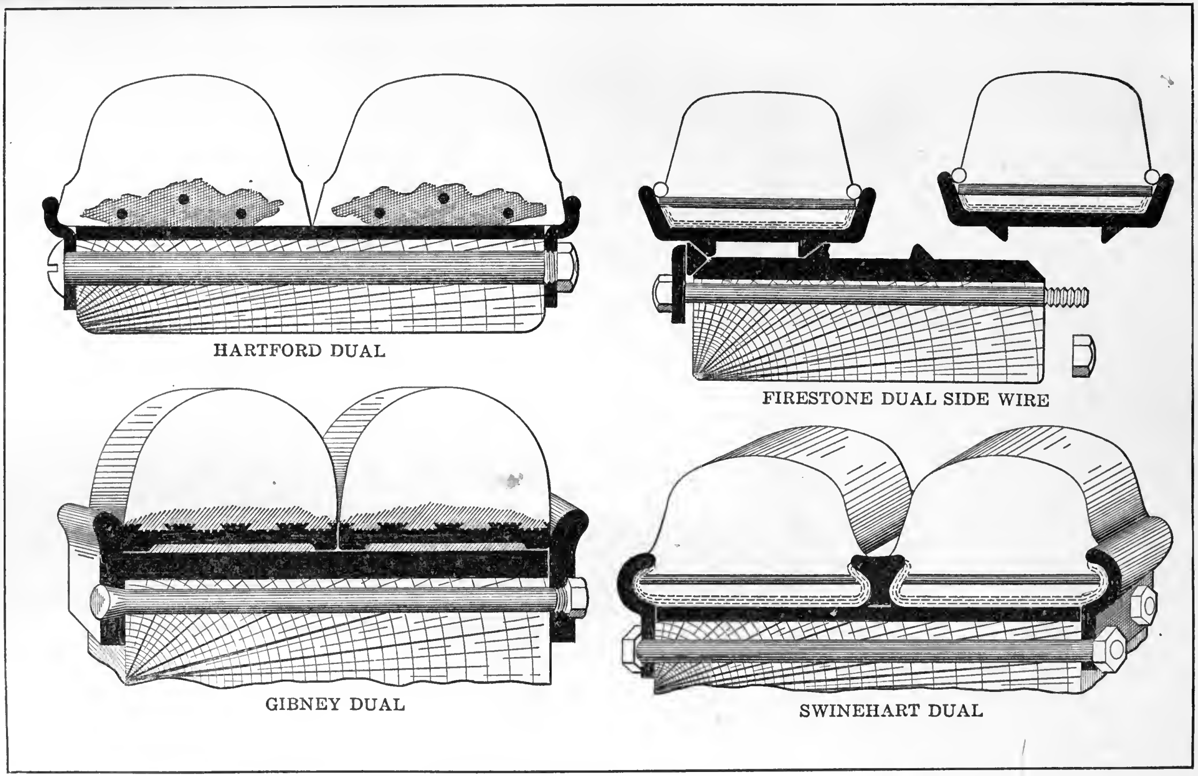


Fig. 321.—Twin Type Solid Tires for Heavy Motor Trucks and Methods of Holding Members in Place on Wheels.

work could only be done at depots where this form of machinery formed part of the equipment. When accident to the tire or natural wear made it necessary to replace the worn member with a new one the wheel had to be removed from the truck and sent to the tire company's station to be fitted up with tires. This meant a loss of

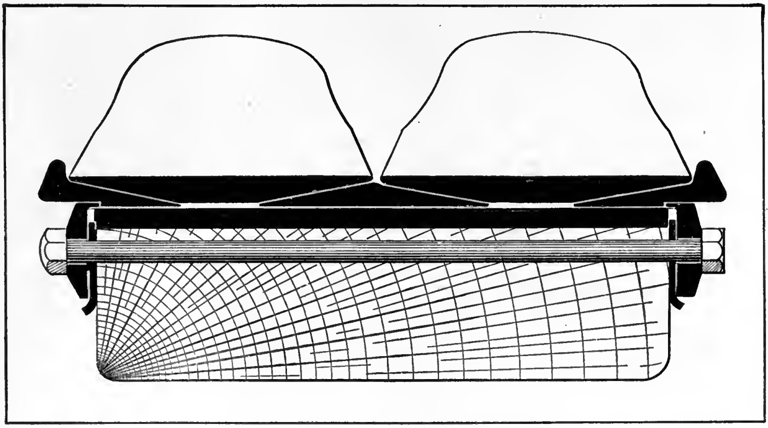


Fig. 322.—Hartford Detachable Twin Solid-Tire Construction.

time of some magnitude, which has been entirely overcome by the new demountable construction. Spare tires may be carried in stock and may be used to replace the damaged members without the use of special applying machinery in most instances and without necessitating the removal of the wheel.

Tools and Supplies for Pneumatic Tire Restoration.—It has been previously stated that one of the chief disadvantages of pneumatic tires has been their liability of failure by puncturing the outer casing and penetrating the inner tube and thus providing a means for escape of the compressed air in the inner tube. The life of a pneumatic tire is decidedly uncertain and will depend on many factors outside of those of purely natural wear. There have been cases where outer casings have given satisfactory service for seven or eight thousand miles, but these instances have been the exception rather than the rule. It is the opinion of most motorists who have had practical experience that if an ordinary set of shoes will give a service averaging two thousand miles that they are equal to the demands made upon them and that they are satisfactory. It may be stated that tires will last longer on light cars than heavy ones and the service obtained from tires fitted to vehicles driven at low and moderate speeds will

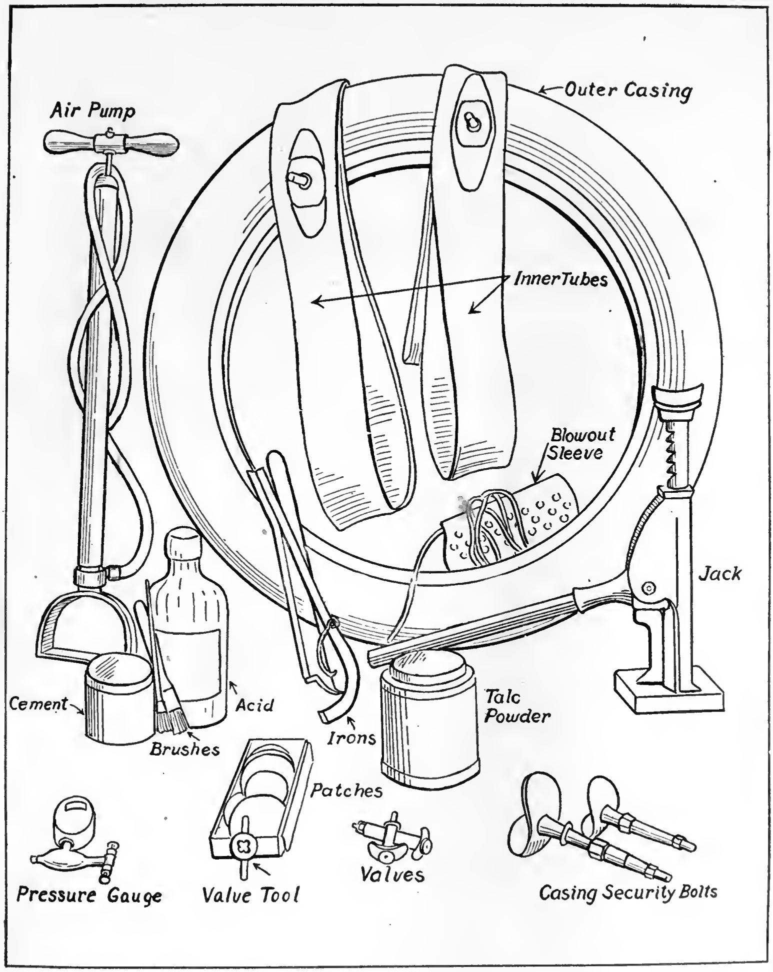


Fig. 323.—Spare Parts and Necessary Repair Equipment for Automobiles Using Pneumatic Tires.

be much greater than that obtained from tires fitted to high-speed vehicles. There is also a personal element which must be taken into consideration, and that is the way that the car is driven and the care taken of the shoes and inner tubes.

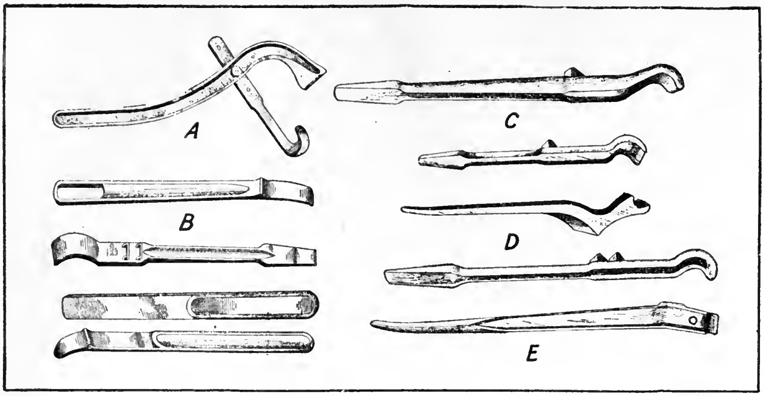


Fig. 324.—Forms of Tire Irons Used in Removing and Repairing Clincher Shoes.

It is necessary, therefore, in all cars using pneumatic tires to carry a certain amount of equipment for handling and repairing these on the road. A typical outfit is shown at Fig. 323, this consisting of a spare outer casing, two extra inner tubes for replacement purposes, a blow-out sleeve, a number of patches, and an acid-cure vulcanizing outfit for applying them. Tire irons must be provided to remove the casing from the rim; the jack is used to raise the wheel of the vehicle on which the defective tire is installed from the ground and make it possible to remove the tire completely from the wheel. The air pump is needed to inflate the repaired tube or the new member inserted to take its place. The talcum powder is sprinkled between the casing and the tube to prevent chafing or heating, while the spare valves and valve tool will be found useful in event of damage to that important component of the inner tube. As it is desirable to inflate the tires to a certain definite pressure, a small gauge which will show the amount of compression in the tire is useful.

The outfit shown may be supplemented by other forms of vulcanizing sets and by special tire irons to make for easier removal of the outer casing. Tire irons vary in design, and most makers of tires provide levers for manipulating the casings, which differ to some extent. A set of tire irons such as would be needed with a clincher-tire equipment could be selected from the forms shown at Fig. 324. That shown at A is utilized to loosen the clincher bead from under the rim should it become rusted in place. After the shoe has been loosened from the rim flange one of the levers of the form shown at B, C, or D would be inserted under the bead in order to lift it over the rim. Two or more of these levers are provided, and the length and form will vary with the preference of the motorist. It will be remembered that the longer levers are more easily operated than the short ones, and that the length of the lever provided will depend entirely upon the size of the tire to be removed.

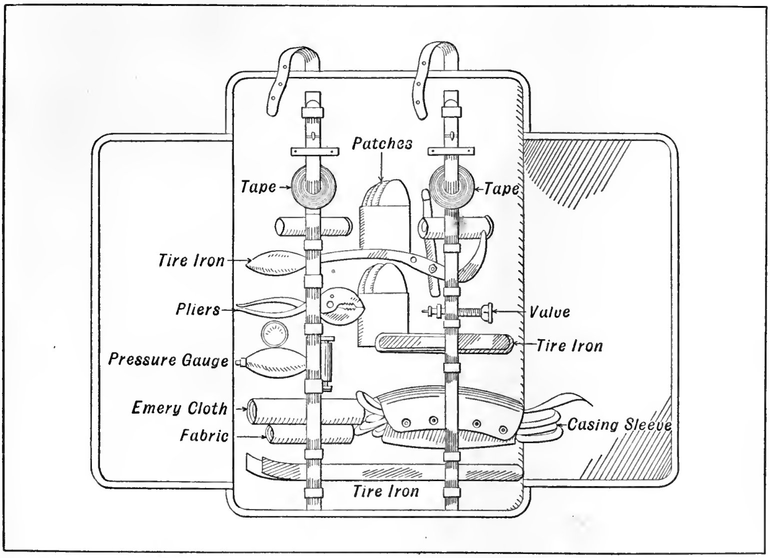


Fig. 325.—Small Repair Kit Containing Necessary Tools and Supplies for Emergency Repairs.

Motorists, as a rule, should carry the releasing lever shown at A, two of the short members depicted at B, and one longer lever, such as the upper one of group C, or the forms D or E. The latter is a combination form which may be used as a jack handle as well as a tire iron, and when it is supplied it is not necessary to carry a jack handle in the equipment. The flattened ends are generally employed for prying the bead from the clincher rim, and when this has been

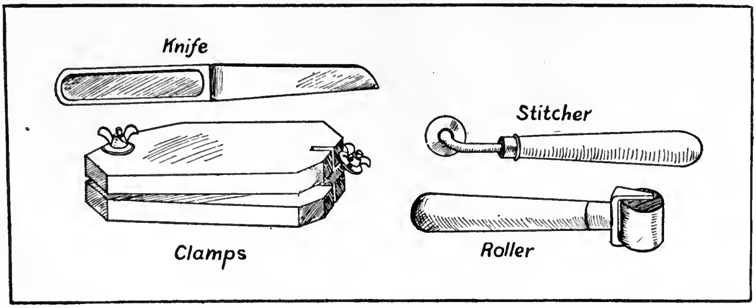


Fig. 326.—Tools Found Useful when Repairing Inner Tubes.

done and sufficient space exists between the bead and the rim to insert the curved end of the larger levers, considerable leverage is obtained and the bead may be lifted over the clincher rim without undue

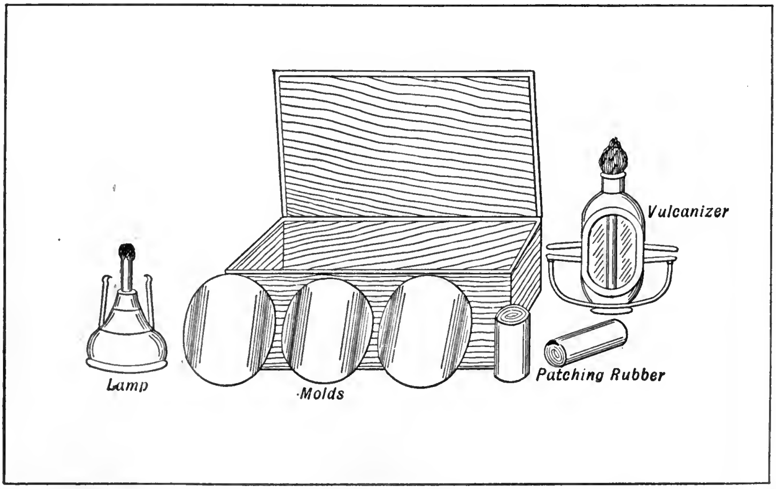


Fig. 327.—Portable Vulcanizer Outfit for Filling Cuts in Outer Casings or Patching Inner Tubes.

exertion. The object of rounding the corners, and of making the working portions as broad as possible, is to reduce the liability of pinching the inner tube, which would be present if the irons had sharp edges.

The tire-repair material is sometimes carried in a special case, as shown at Fig. 325, this consisting of all parts necessary to make temporary repairs to be considered in proper sequence. This outfit is sometimes supplemented by the special tools shown at Fig. 326. The knife is used to cut the rubber, trim patches, etc. The stitcher and roller are useful in rolling the patch after it has been cemented

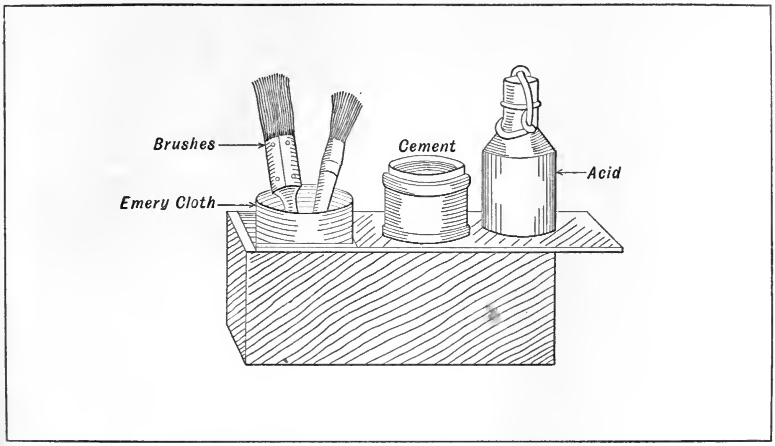


Fig. 328.—Acid-Cure Vulcanizing Outfit.

to the tire to insure adhesion of the patch with the tube, while the wooden clamps are useful in binding the patch firmly against the damaged portion of the tube while the cement is drying. Some motorists carry small vulcanizers in order to effect more permanent repairs than would be possible with the simple patching processes in which the adhesive powers of cement are utilized. A simple steam vulcanizer and molds for use in connection with it are shown at Fig. 327, and an acid-cure vulcanizing set which does not make use of any form of heating apparatus is shown at Fig. 328.

Tire-Manipulation Hints.—In removing or replacing outer casings considerable care must be exercised not to injure the shoe or pinch the inner tube. The first step is to jack up the wheel from which the defective tire is to be removed, this relieving the wheel of the car weight. The valve inside is then unscrewed in order to allow any air that may remain in the tube to escape, and then the lock nuts on the valve stem and security bolts are removed so that these members may be lifted to release the clincher beads from the rim channels. If the tire is stiff or has not been removed for some

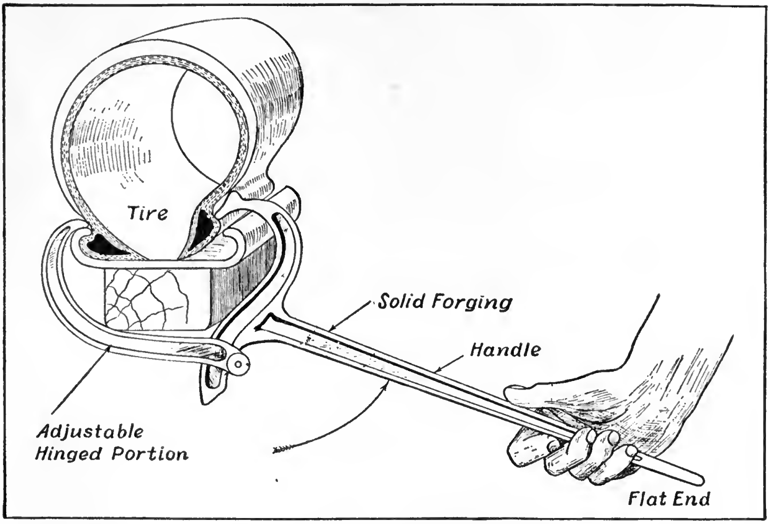


Fig. 329.—Special Appliance for Loosening Clincher Shoes from Rim of Wheel.

time, a special iron, such as depicted at Fig. 329, is utilized in the manner shown, and the beads are pushed clear of the clincher rim. When the casing has been loosened on one side, a flat tool, such as shown at Fig. 324, B, is inserted under the loose bead to act as a pry or lever to work the edge of the casing gradually over the rim.

Very long levers are necessary to handle heavy, stiff tires, and new casings are particularly hard to remove. The shorter irons may be employed on the smaller casings and on shoes which have been used for some time and which are more pliable than the new ones. Two of the levers are generally used together, one being kept under the loosened edge of the bead, while the other is used to force the bead over the edge of the rim. When the outside edge of the bead has been forced over the rim at all points the inner tube is lifted from the rim and is pulled out of the shoe. The start at removing is made at the point diametrically opposite the valve stem. When this portion has been pulled clear of the rim and out of the casing it is not difficult to pull the rest of the tube out and finally lift the valve stem out of the hole through which it passes in the wheel felloe, and take the inner tube entirely off the wheel.

If the casing demands attention, or if a new case is to be used, the inside bead is worked over the channel of the clincher rim in just the same manner as was done with the outside bead, and after a start has been made and a portion of the inside bead forced over the rim there will be no difficulty in slipping the entire shoe from the wheel. Applying a tire is just the reverse to removing one. The first operation is to place the inner bead of the tire in position in the center of the rim by forcing it over the outside flange. This is done gradually, and in order to force the remaining portion of the shoe it may be necessary to use long levers when the greater part of the casing has been applied. The next step is to work the shoe gradually toward the inner channel of the rim, then to insert the security bolts in the holes made to receive them.

The inner tube is replaced after it has been partially inflated by putting the valve stem in first and then inserting the rest of the tube, being careful not to pinch it under the heads of the lugs or security bolts. After the inner tube has been put in place the outer bead of the tire is worked over the edge of the rim, the portion adjacent to the valve stem being inserted first. When working the remainder of the bead over the rim channel much care must be exercised to insure that the inner tube will not be pinched by the sharp edges of the tire levers. The object of partially inflating the inner tube is to distend it so there are no loose or flabby portions that are liable to catch under the tire bead when this is being forced in place over the wheel rim.

The mechanically fastened tires are much easier to remove than clincher shoes, because after the retaining rims are taken off the wheels the outer casings can usually be pulled right off the flat rim. The tools and the manner of using them employed in taking off Fisk bolted-on tires are shown at Fig. 330. The clamp is employed when replacing the shoe and it serves to hold the retaining ring and

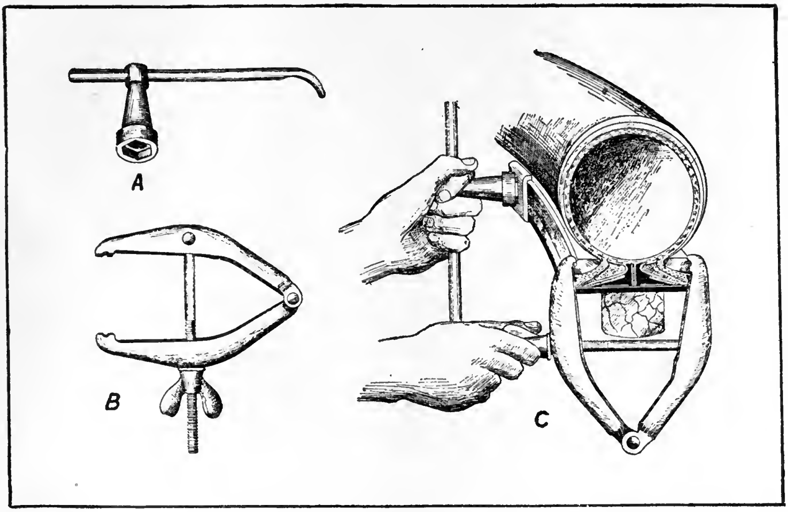


Fig. 330.—Tools for Removing Fisk " Bolted On " Casings and Method of Using Them.

the bottom of the shoe closed in such a way that the nuts on the through bolts may be easily tightened up by using a socket wrench depicted at A. This wrench has a T handle with a hook end, and this hook is sometimes of value in prying off a retaining ring that has become rusted in place. The method of handling these tools and this type of tire are so clearly shown that further description seems unnecessary.

Tire-removing tools are made in many forms, and more have been devised for use with clincher type of casings than the other forms because the beads on these casings sometimes become so firmly imbedded in the rim channels that it is extremely difficult to remove them, especially if the shoe has been on the rim for some time. Another form of removing tool possessing a certain amount of adjustability which makes it adaptable for use in connection with varying sizes of clincher casings, and the method of use, is shown at Fig. 331. In this form the main or handle portion has a piece extending from it that carries a rubber roll designed to pull against the spoke. The part that bears against the shoe is a separate piece, provided with a number of hooks to make it possible to alter its position as desired. For use with a small tube the uppermost notch is used, and as the shoes become larger the notched piece is pulled farther up in the slot in which it slides on the head of the Y-shaped handle. Tools of this nature are extremely useful and should form part of the equipmen of every motorist who uses clincher tires.

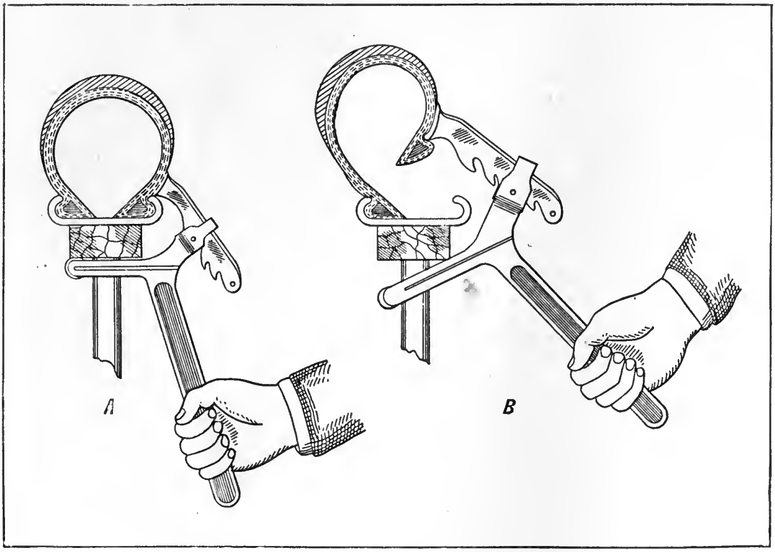


Fig. 331.—Adjustable Iron for Loosening Clincher Casings That Have Stuck to Rims.

Rules for Tire Selection and Inflation.—The tires used on motor cars are generally selected by considering the amount of load sustained by the wheels of the cars, but considerable difference of opinion seems to obtain regarding the way the weights should be estimated. Tire manufacturers believe that the entire weight of the vehicle with all possible equipment and passengers must be considered, but there have been cases where a car has been supplied with tires that were inadequate because only the weight of the car was considered in making the selection and the added load of passengers and equipment was disregarded. It is believed desirable to provide rear tires that will be twenty-five per cent larger than those needed merely to support the weight of the rear end of the vehicle, because in the majority of cases these members are called upon to sustain stresses incidental to traction as well as the strains produced by the vehicle weight.

It is customary to use one size tire on the four wheels, the thought being that the shoes from the front wheels, which are not subjected to the severe service that those on the rear are called upon to endure, can be placed on the rear wheels when those casings become weakened by use, and their place taken by the weakened rear shoe, which may have sufficient capacity to do the work expected of front-wheel tires. The following table gives the proportion between vehicle weights and tire sizes that are commonly accepted by tire manufacturers. These figures are based on the maximum permissible weight of a car without passengers, but as they do not consider the factor of possibilities of overload, and if a motorist is having tire

PROPORTIONS BETWEEN AXLE LOADS AND TIRE SIZES ADOPTED BY AMERICAN TIRE MAKERS

2½-inch tires, all diameters	225 pounds per wheel
3 inch tires, all diameters	350 " " "
3½ x 28-inch tires	400 " " "
3½ x 30-inch tires	450 " " "
3½ x 32-inch tires	555 " " "
3½ x 34-inch tires	600 " " "
3½ x 36-inch tires	600 " " "
4 x 30-inch tires	550 " " "
4 x 32-inch tires	650 " " "
4 x 34-inch tires	700 " " "
4 x 36-inch tires	750 " " "
4½ x 32-inch tires	700 " " "
4½ x 34-inch tires	800 " " "
4½ x 36-inch tires	900 " " "

For weights in excess of 1,000 pounds per wheel, 5-inch tires and over are recommended. Weights given apply to car without passengers.

troubles, it would be well to provide tires that are oversize and of more than sufficient capacity. Such members are not only more enduring than shoes which are barely up to the requirements, but they are not liable to blow out or deteriorate as fast as overloaded tires.

Next to the selection of proper size tires the important consideration is that these be kept properly inflated. If a tire is not properly filled with air it will flatten out, and the tendency will be to separate the layers of fabric and rubber of which the shoe is composed, because of the alteration of the almost round or tubular section that the tire is supposed to be when in use. If a tire is properly inflated the walls will be braced from inside by the pressure of the compressed air in the inner tube, and the flattening effect will have no perceptible effect in producing disintegration of the fabric and rubber plies of the casing. The figures given in tables which follow are those recommended by leading tire manufacturers as being most suitable for the various sizes of tires listed.

These usually take into account the increase in temperature and resulting pressure of the air created by the friction between the tires and the roads caused by prolonged running. A French authority has made a series of tests to determine what the increase of pressure would be on tires from three to four and a half inches in diameter under usual touring-car service conditions. These results are presented in tabular form and should prove very interesting. The increase with larger tires is greater in proportion because the walls of the casings are heavier and stiffer and greater internal strains are produced in the fabric by the distortion of the shoe at the points of bending.

AIR PRESSURES FOR INFLATING PNEUMATIC TIRES RECOMMENDED BY LEADING MAKERS

Diameter of Tire, Inches	Maximum Weight on Wheel, lbs.	Air Pressure in Tire, lbs. per Square Inch
2½	225	50
3	350	60
3½	600	70
4	750	80
4½	1,000	90
5	1,000	90

INCREASE IN AIR PRESSURES CAUSED BY DRIVING

Initial Pressure in Tire, Cold	Working Pressure in Tire, Warm	Increase Resulting from Work
Lbs. per Sq. In.	*Lbs. per Sq. In.*	*Lbs. per Sq. In.*
71.116	88.183	17.067
85.339	105.750	20.411
99.562	123.546	23.984
113.785	141.920	28.135
128.008	158.588	30.580
142.232	176.368	34.136

The conventional method of inflating tires by using a foot pump does not always insure that the tire will receive adequate inflation, and when a pump is employed it is imperative that some form of gauge be provided that will register the amount of pressure inside of the tire in order that it will reach the figure recommended by the tire makers. Different methods of tire inflation have been devised which eliminate the necessity of using manually operated pumps. Obviously a simple expedient would be to provide a small power-driven pump that could be actuated by any convenient mechanical connection with the engine. Another method is to use an air bottle, which is a steel container in which air is stored under great pressure. The air is compressed to such a point that a tank less than two feet long and six inches in diameter will furnish sufficient air to inflate seven or eight tires of average size, or twelve to fourteen small ones. The tanks may be exchanged at small expense when exhausted for new containers holding a fresh supply of air. In some tanks gases of various kinds under high pressure are used and the motorist may obtain these on the same basis as air bottles are supplied.

All devices of this character are fitted with gauges to indicate the amount of pressure in the tire, and to prevent overinflation. If a tire is not properly inflated the shoe will be liable to various kinds of road damage and will be easily punctured, while if the pressure is too high the shoe is liable to "blow-out" at any weak point in the structure. A tire-pressure gauge is a very necessary article of equipment in any car and its proper use when blowing up tires will insure the best possible results if the schedule recommended by the tire manufacturers is adhered to.

Tire Repair and Maintenance.—The common causes of tire failure that the motorist is apt to encounter are shown at Fig. 332. The

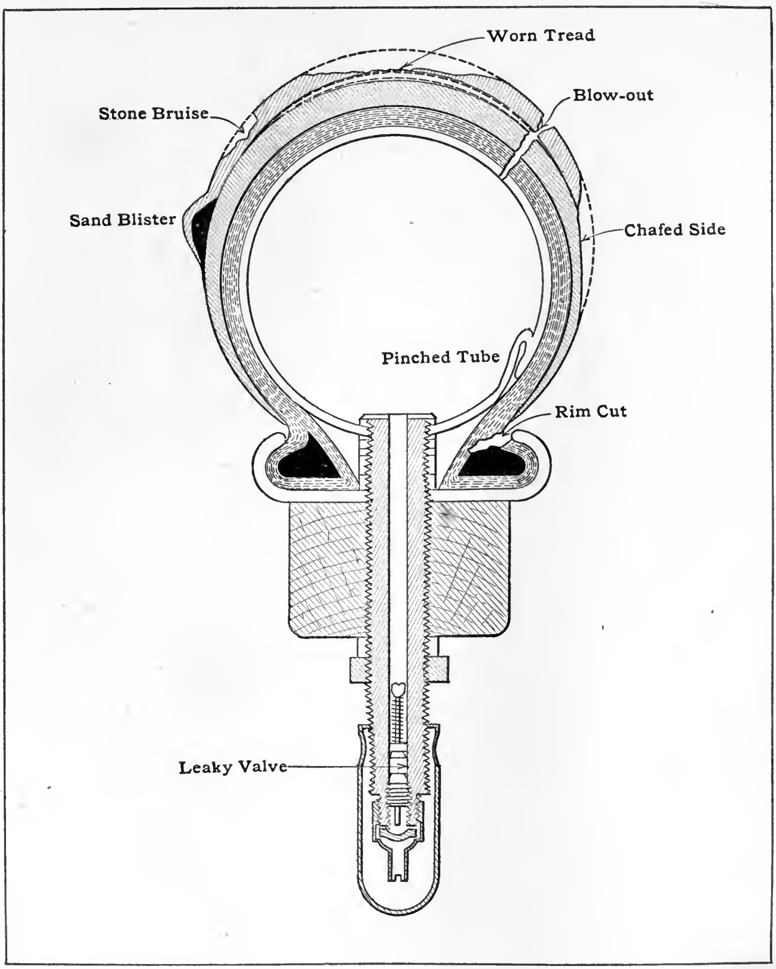


Fig. 332.—Sectional View of Pneumatic Tire Showing Some Conditions Which Cause Failure.

most common is natural wear of the tread portion of the tire. The rubber compound in contact with the road surface wears away in time, and the fabric layers which constitute the breaker strips are exposed. The shoe is weakened and any sharp object in the road is apt to penetrate the weakened case and puncture the inner tube. If a number of the layers of fabric comprising the body of the shoe are cut this constitutes a weak place in the casing and a blow-out will result because the few layers of fabric remaining do not have sufficient strength to resist the air pressure.

A stone bruise is caused by the removal of a portion of the rubber tread by a sharp stone, piece of glass, etc., and is much more serious than a puncture because it removes some of the tire, whereas in ordinary cases of puncture a sharp object merely penetrates the casing. A sand blister is produced by sand or grit from the road working into a space in the tire between the tread and the fabric body through some neglected incision or bruise. The side of the tread is often chafed by running the tires against curb stones or by driving in car tracks. Rim cutting is generally caused by insufficient inflation which permits the rim to cut into the tire and thus tends to sever the bead from the side of the shoe.

The chief inner tube trouble is penetration of the wall by some sharp object, or the folding over of part of the tube walls when the tire was applied. The parts of the check valve sometimes give trouble and the valve leaks. In cases of valve trouble it is usually cheaper to replace the valve inside than it is to attempt to fix it. Some of the causes of valve leakage are hardening of the rubber washer, bent stem, which prevents the valve from seating properly or a particle of dust or other foreign matter which would act to keep the valve from closing the air passage positively.

The most serious condition that a motorist will meet with is a "blow-out" and usually only temporary repairs can be made on the road. The common methods of restoring a defective outer casing are depicted at Fig. 333. In this an inner sleeve, which is composed of a number of plies of fabric, is placed between the inner tube and the broken portion of the outer casing to prevent pinching of the inner tube by the jagged edges of the cut, and to strengthen the casing from the outside an outer shoe or gaiter made of leather is laced around the shoe. The object of using both inside and outside reënforcing members in combination is to not only strengthen the weak outer casing but by providing an outer shoe dirt is kept from working into the tire.

Punctured inner tubes may be temporarily repaired by using a cemented surface patch. The first step necessary is to clean the surface of the tube very thoroughly with gasoline and then to rough up the surface of both patch and portion of the tube surrounding the

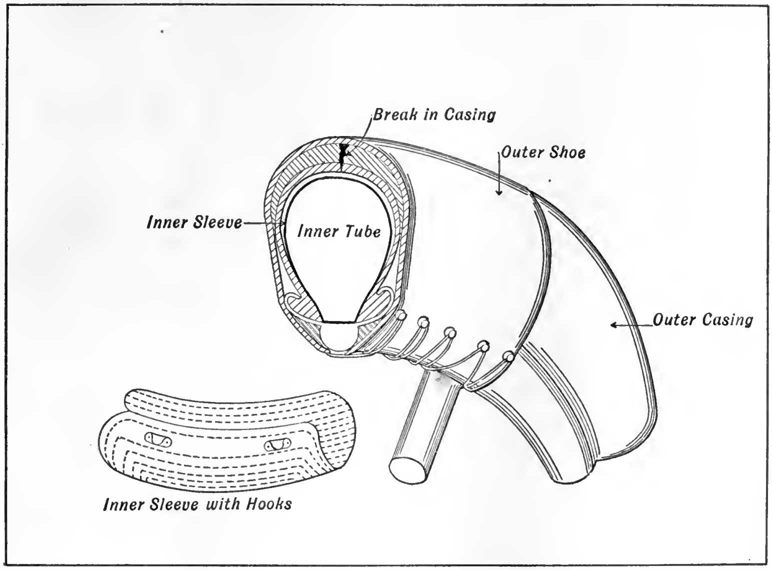


Fig. 333.—Temporary Casing Repairs Possible When Small Blow-Out or Large Puncture Occurs on the Road.

holes with a wire scratch brush or with sandpaper. After the surfaces are properly cleaned and roughened the patch and the tube are coated with suitable patching cement which is allowed to become thoroughly dry before the second coat is applied. The second coat is allowed to become "tacky," which expresses a condition where the cement is almost dry and yet still possesses a certain degree of adhesiveness. The patch is applied to the cemented portion of the tube and the whole is clamped firmly together to secure positive adhesion while the cementing medium is drying. Patches should always be of sufficient size to cover the damaged portion and at the same time have about three quarters of an inch or more of the patch at all sides of the orifice.

Very satisfactory repairs to both inner tubes and outer casings of a permanent nature can be made by using small portable vulcanizers which may be heated by either electricity or vapor. When these are used a special vulcanizing cement is necessary and uncured rubber stock must be used for patching or filling openings caused by punctures or blow-outs. The patch of raw material is applied to the cemented surface of the tube or casing and the vulcanizer heated to the proper temperature. The heat of the vulcanizer causes the rubber of the patch to unite perfectly with the old material and forms an intimate bond.

In vulcanizing the most important precaution is to maintain a proper temperature. Too great a degree of heat will burn the rubber, while a proper cure cannot be effected if the temperature is too low. The temperatures recommended for vulcanizing vary from 250 to 375 degrees F. The lower degree of heat is used in working material that has been previously cured, while the higher temperature is recommended for new rubber. A number of small portable vulcanizers and their method of use is shown at Fig. 334. In the view at A the vulcanizer is heated by electric current and is provided with two faces, one flat, designed for use against inner tubes, and the other curved to conform to the curvature of outer casings. In the view A the vulcanizer is shown with the flat face in use, while at B it is shown clamped to an outer casing with the curved face in contact with the tread. The heat is obtained by passing a current of electricity through suitable resistance coils imbedded in the body of the device.

Where electric current is not available various forms of flame-heated vulcanizers may be used. In that form depicted at C the vulcanizer body is filled with water, which is converted into steam by the heat of a flame furnished by the alcohol lamp that forms part of the device. This form of vulcanizer is provided with a flat face as well as a curved one and can be used for either inner tube or outer casing restoration. A combination vulcanizer which is composed of a large hollow cast-iron body filled with water and heated with a spirit lamp is depicted at D. In this the curved face and the flat

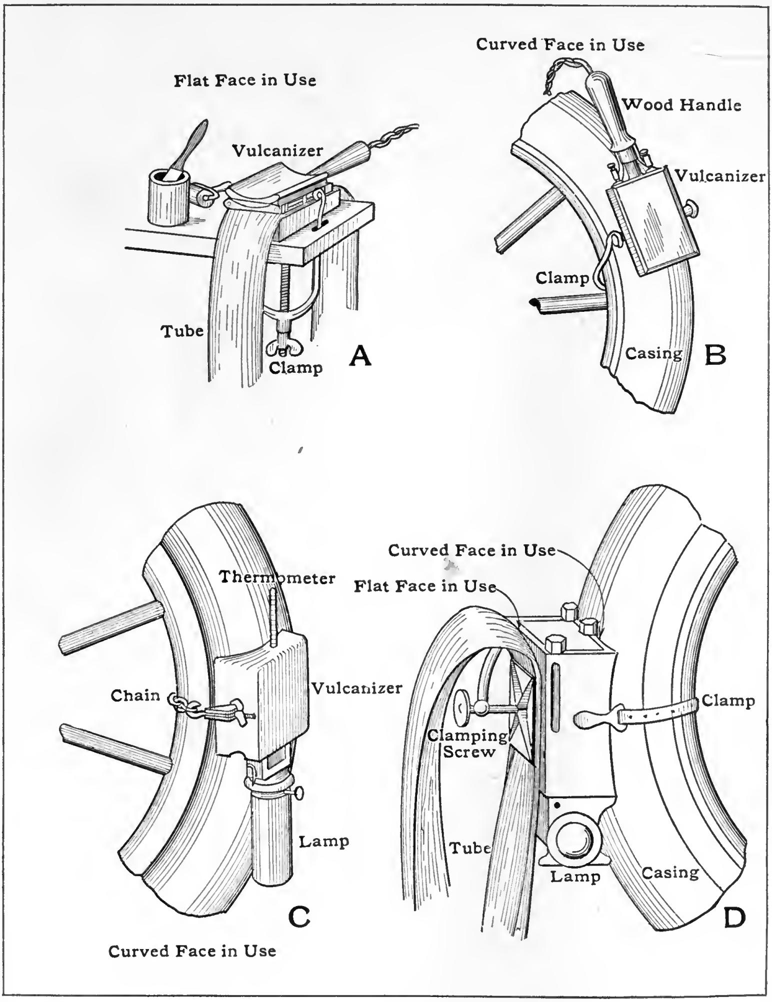


Fig. 334.—Methods of Using Small Electric or Vapor Vulcanizers on Tube and Casing Work, a Very Convenient Method of Effecting Permanent Repairs.

face may be used simultaneously and an inner tube patched at the same time that the outer casing is being treated. As very complete instructions are furnished with these small vulcanizers, any motorist may become familiar with their use without much difficulty.

In describing the methods of removing clincher casings special emphasis was laid on the necessity of careful manipulation to prevent pinching of the inner tube. The manner in which this somewhat

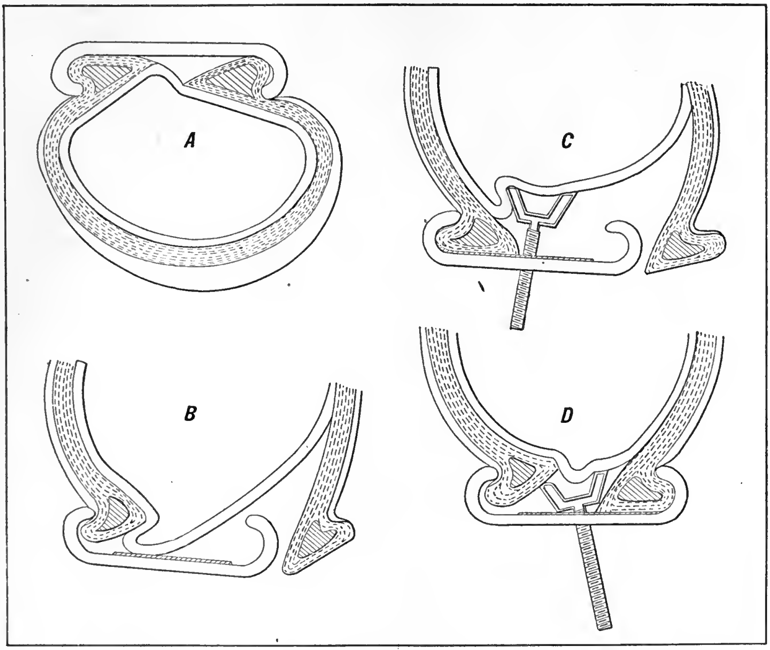


Fig. 335.—How Inner Tubes May Be Pinched and Ruptured if Outer Casing is Replaced Carelessly or if Tire Lugs Are Not Properly Placed.

delicate member may be ruptured when applying or removing outer casings may be easily understood by reference to Fig. 335. At A the inner tube is pinched by a poorly fitting bead which does not bed properly into the channel of the rim. At B a portion of the inner tube has been caught under the bead of the shoe when this was applied because the tube was not properly inflated before it was inserted into the casing. At C and D the inner tube has been pinched by carelessly placed or poorly fitting security bolt.

The rules to secure satisfactory operation from pneumatic tires may be easily summed up. In the first place it is imperative that the tires be inflated to the pressures recommended by the manufacturers and that they be selected with a certain margin of safety over the actual requirements. The tires should be kept clean and free from oil or grease because the oleaginous substances used for lubrication very quickly attack rubber compounds and cause crumbling and rapid deterioration. Oil or grease should be wiped off as soon as noticed and the tire cleaned by the application of gasoline. Any small cuts or openings in the tire that may permit water to enter or sand to work between the fabric and the tread will cause trouble in time. One should be careful in driving not to apply the brakes too suddenly because this will lock the wheels and wear the tire very quickly. Care should be taken not to drive in car tracks, and when highways do not have the proper surface they should be negotiated very carefully to avoid cutting the casings.

CHAPTER XI

Motor-Car Equipment and Accessories—Air- and Gas-Operated Engine Starters—Electric Starting Systems—Gas- and Electric-Lighting Appliances and Their Use—Wind-Shield Forms—Shock Absorbers—Speedometer and Mileage Indicators—Tool Equipment for Ordinary Repairs—Miscellaneous Supplies of Value to the Motorist—How Supplies are Carried.

Coincident with the development of the motor car there has been produced a large number of accessories, some of which make for greater comfort while touring and others that have material influence on the safety of the car and its occupants. Many accessories have been devised for application to motor cars of various classes, but many of these are not necessary and have but little real merit. In this exposition the writer will confine his remarks to tried and proven auxiliaries desirable to include in the motor-car equipment and which may really be regarded as necessary to obtain the maximum amount of pleasure and profit possible from motoring.

Many of the devices listed are now supplied by manufacturers as regular equipment because they are considered as much a part of the car as some of the more important components belonging to the mechanism proper. Other devices of considerable value must be furnished by the motorist himself and when one tries to make selections from the stock of the average supply house it is quite difficult to differentiate between the valuable and necessary accessories and those which are not needed unless one is guided largely by the experience of others.

Self-Starters for Gasoline Engines.—One of the disadvantages of the gasoline engine which has been often advanced by those favoring steam or electric power is that it is difficult to start it in some cases, and various means were devised to overcome the objection advanced. The early gas engines fitted with poorly designed carburetors and inadequate ignition systems were often difficult to set in motion, but as the gasoline engine was improved and the multiple-cylinder form gained in favor, those used during the past few years have been easy to start by some form of starting handle or crank and often a quarter turn of that member is sufficient to set the engine in motion if it was in proper adjustment and the various auxiliary groups were functioning properly. At the present time the improvements made in the gasoline automobile have been more in the nature of detailed refinement and those engaged in producing motor cars have studied more carefully the various points which make automobiles more convenient and more easily operated. The requirements of the present day cannot be met by easy starting motors because this feature is common to all automobiles from the smallest runabout to the heaviest touring car or truck.

The present demand is for engines that are equipped with some form of mechanism which will make them self-starting, that is, so that they may be set in motion by merely pressing a button or pushing a valve from the seat and not by the usual form of hand crank at the front of the car. The starting handle has always been a danger point and many broken arms and fractured wrists have resulted from a premature explosion of gas in the cylinders which forced the starting handle backward and against the arm or hand of the person starting the engine. Motor-car control has been simplified to a point where many women are running cars, but the average motor requires the expenditure of more strength than that possessed by the average woman or young person to start it. When a separate starting device is fitted the motor may be started as easily by a person lacking in strength as by one who can " spin " the engine around at will.

Self-starters operate on two principles. First, that in which the crank shaft is rotated by some form of external mechanism which causes the pistons to draw in a charge of gas in the usual manner and which is merely a mechanical substitute for hand cranking. Second, those systems in which a charge of gas is supplied the cylinders and ignited independently of crank-shaft rotation. Mechanical starters include all devices which rotate the shaft to produce the cycle of operations necessary to secure the power impulse in the cylinders, and motion may be imparted to the crank shaft in two ways: by the use of independent mechanism, or by making a motor of the engine itself.

The independent motor devices may be spring, air, or electrically operated mechanisms. Spring motors have not attained the popularity that air or electric motors have because they weigh considerable and occupy more space than would be needed by the other types. Their capacity is limited because the energy is supplied by a spring

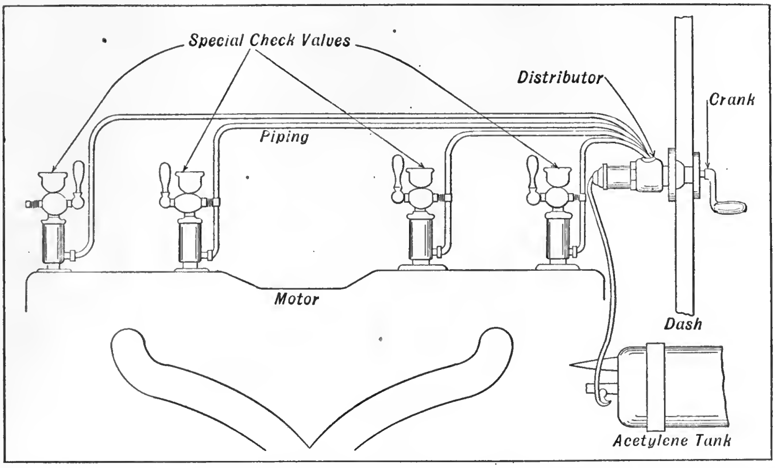


Fig. 336.—Simple Ignition Starting System Using Acetylene Gas and Hand-Operated Distribution Valve on Dash.

or springs which become unwound and which cannot supply any energy when they are uncoiled. Spring motors are usually geared to the crank shaft and thrown out of gear by automatic means after the engine is started when the springs have been wound to the proper degree of tension. Air and electric motors have received some application, but as a general rule it is the simpler ignition starters that are the vogue.

Features of Ignition Starters.—It is not an uncommon thing to start a four- or six-cylinder motor by merely turning on a switch because a certain amount of unexploded gas may remain in one of the cylinders and this may be compressed to a point where it will explode as soon as an electric spark takes place in the cylinder to fire the gas. It is natural, then, that the first starting systems proposed should incorporate some means of furnishing a charge of gas to the engine and then exploding it. The gas supplied may be either carbureted gasoline or acetylene and the conditions which exist are similar to those present when the engine is started on the spark.

A simple form of gas-starting systems is outlined at Fig. 336. Special check valves are inserted in each cylinder head of the four-cylinder motor and are supplied with gas through a special form of hand-operated rotary distributor valve carried on the dash. The gas is supplied from an acetylene tank and one or two turns of the distributor handle serves to supply gas to the cylinder, the piston of which is at the upper center and in the proper position to receive the impact of the exploded gas. Turning on the switch, provided that the car is a form using battery ignition as an auxiliary or regular system, will suffice to produce a spark in the cylinder to which the gas has been introduced and will start the motor.

Gasoline is sometimes used as a starting medium and when this is employed some form of pump is used to force an explosive vapor into the cylinder. An upward movement of the pump handle draws in a certain amount of gasoline from the tank and air through some

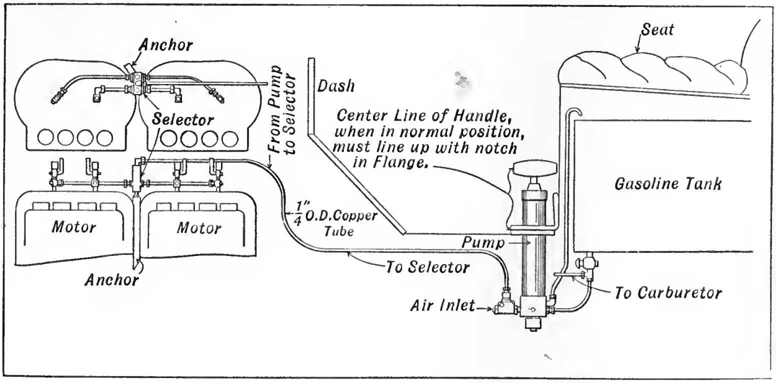


Fig. 337.—Ignition Starting System in which a Hand-Operated Pump Forces Mixture to Cylinders.

form of special inlet check, and when the pump handle is depressed the gasoline mixture is pumped into the proper cylinder through a pipe which is attached to some form of distributor or selector valve to direct the gas stream to the proper explosion chamber. A system which depends upon supplying gas is shown at Fig. 337. In this the hand pump is placed in front of the operator's seat in such a position that the handle may be conveniently reached by the driver or passenger. A couple of strokes of the pump suffices to supply enough explosive mixture to start the engine when the ignition circuit is completed. The gasoline-starting system is not as popular as that using acetylene gas because the latter gas will explode easier and the operator does not need to exercise the degree of judgment that is needed when supplying a gasoline vapor.

Compressed-Air Starting Systems.—Two forms of air-starting systems are in general use, one in which the crank shaft is turned by means of an air motor, the other class where compressed air is admitted to the cylinders proper and the motor turned over because of

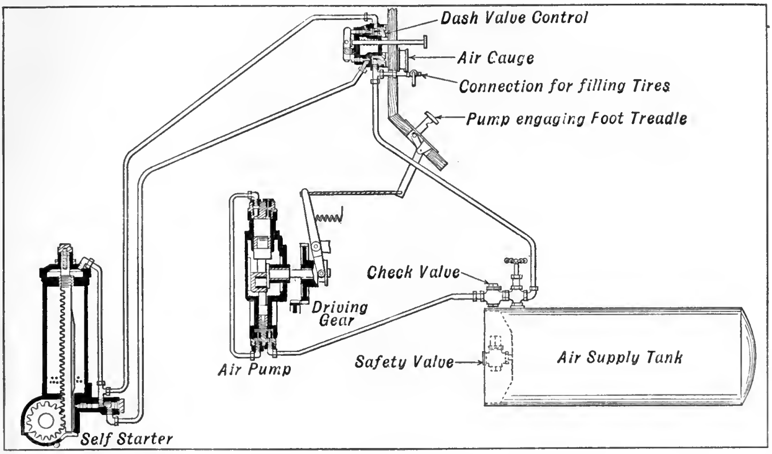


Fig. 338.—Never-Miss Starting System with Special Air Motor for Mechanical Cranking.

the air pressure acting on the pistons. A system known as the "Never-Miss" is shown at Fig. 338. In this a small double-cylinder air pump is driven from the engine by means of suitable gearing and supplies air to a substantial container located at some convenient point on the chassis. The air is piped from the container to a dash-control valve and from this member to a peculiar form of air motor mounted near the crank shaft. The air motor consists of a piston to which a rack is fastened which engages a gear mounted on the crank shaft provided with some form of ratchet clutch to permit it to revolve only in one direction, and then only when the gear is turning faster than the engine crank shaft.

The method of operation is extremely simple, the dash-control valve admitting air from the supply tank to the top of the pump cylinder. When in the position shown in cut the air pressure will force the piston and rack down and set the engine in motion. The

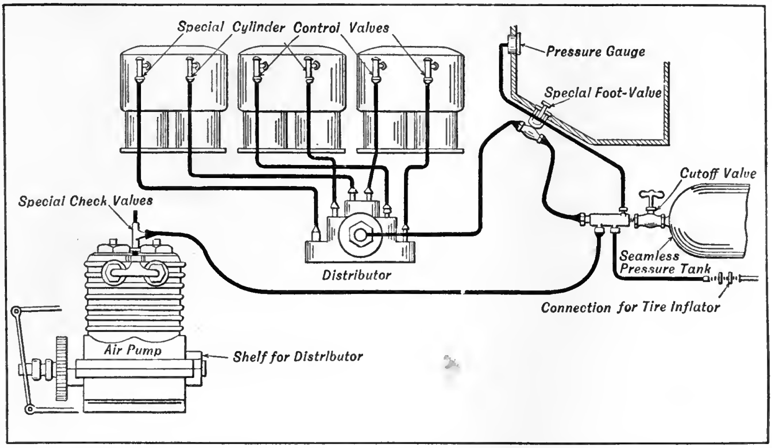


Fig. 339.—Janney-Steinmetz Compressed-Air Starting System.

valve is a special form and the piping is arranged in such a manner that a current of air may be sent against the bottom of the piston when it has reached the end of its stroke to return it to the top of the pump cylinder. When the piston reaches the bottom of its stroke, the air is automatically discharged through a series of exhaust openings in the cylinder wall.

An air gauge is placed on the dash so that the pressure of air in the supply tank may be ascertained at a glance. If the pressure is lower than it should be a foot treadle is depressed and the air pump put into action by meshing the driven gear on the pump crank shaft with the driving member that supplies power from the engine. When the air pressure is sufficiently high the treadle is released and the pump ceases to supply air. A safety valve is installed on the tank to relieve any excess pressure which might accumulate if the pump is kept in action longer than needed.

Another form of air-starting system in which air is supplied directly to the cylinders of the motor through a special distributor arrangement is shown at Fig. 339. The small air pump is driven by gear connection from the engine in the usual manner, and supplies air to a pressure tank. The distributor is driven in much the same manner and at the same speed as an ignition distributor used on a magneto, and the arrangement of piping is such that the air is

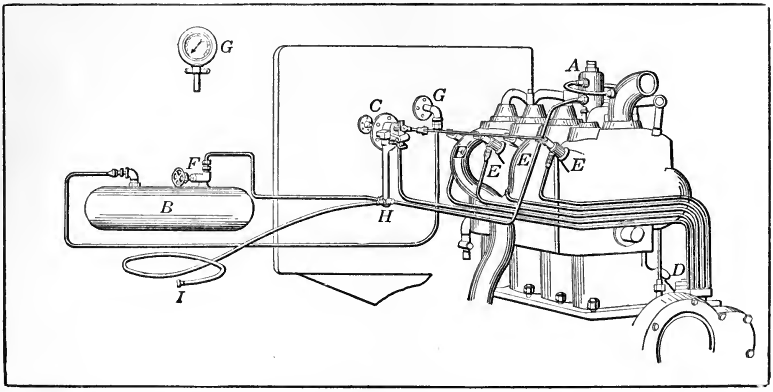


Fig. 340.—Parts of Air-Starting Group Supplied on Chalmers Cars. A—Pressure-Supply Valve. B—Compressed Gas Tank. C—Dash Starting Button. D—Mechanical Distributor. E—Cylinder Check Valves. F—Gas Shut-Off. G—Pressure Gauge on Dash. H and I—Air Connection for Tire Inflation.

supplied to the cylinders in the regular firing order. When the foot valve is depressed air is admitted to the cylinders and the engine is kept in motion by air pressure until it has inspired a charge of gas which becomes ignited and starts the motor on its cycle of operation.

The starter used on the Chalmers car and fitted to the car as an integral part of the power plant is shown at Fig. 340. In this a check valve in the head of Number 1 cylinder stores air under pressure in a tank carried in the body of the car. A dash valve releases air from the tank when it is desired to start the motor and this is carried to a distributor operating upon the same principles as the usual form of ignition commutator. The compressed air is sent to the cylinders which are ready for firing and in this way the motor is operated and the crank shaft turned by the air pressure until sufficient gas has been drawn in from the carburetor by the downwardly moving piston to make ignition effective. One of the disadvantages of the air-starting system shown at Figs. 339 and 340 is that these are not effective if the motor should stop on dead center, i. e., when the piston in the working cylinder is exactly at the top of its stroke. This condition is one that seldom obtains in a gasoline engine because the natural tendency is for the pistons to balance themselves in such a way that they are nearer the middle of their stroke than the dead center position. Should a motor stop on dead center it may be easily turned over a small amount by the hand crank and then the self-starting device immediately becomes operative. One of the advantages of these systems is that they furnish air for tire inflation as well as for motor-starting purposes. When used on a six-cylinder engine the objection advanced that the motor is liable to stop on dead center is not to be considered as with a four-cylinder motor.

Electric Starting Systems.—Starters utilizing electric motors to turn over the engine have been recently developed, and when properly made and maintained in an efficient condition they answer all the requirements of an ideal starting device. The capacity is very high, as the motor may draw current from a storage battery and keep the engine turning over for half an hour on a charge. The objection against their use is that it requires considerable complicated and costly apparatus which is difficult to understand and which requires the services of an expert electrician to repair should it get out of order.

A typical electric starter, such as used on the Cadillac car, is outlined at Fig. 341. The apparatus necessary consists of some source of electric-current supply, means for storing electricity, and some method of applying the power to rotate the engine. In the Cadillac system the electric current is generated by a combined motor generator permanently geared to the engine. When the motor is running it turns the armature and the motor generator is acting as a dynamo, only supplying current to a storage battery. On account of the varying speeds of the generator, which are due to the fluctuation in engine speed, some form of automatic switch which will disconnect the generator from the battery at such times that the motor speed is not sufficiently high to generate a current stronger than that delivered by the battery is needed. These automatic switches are the only delicate part of the entire apparatus, and while they require very delicate adjustment they seem to perform very satisfactorily in practice.

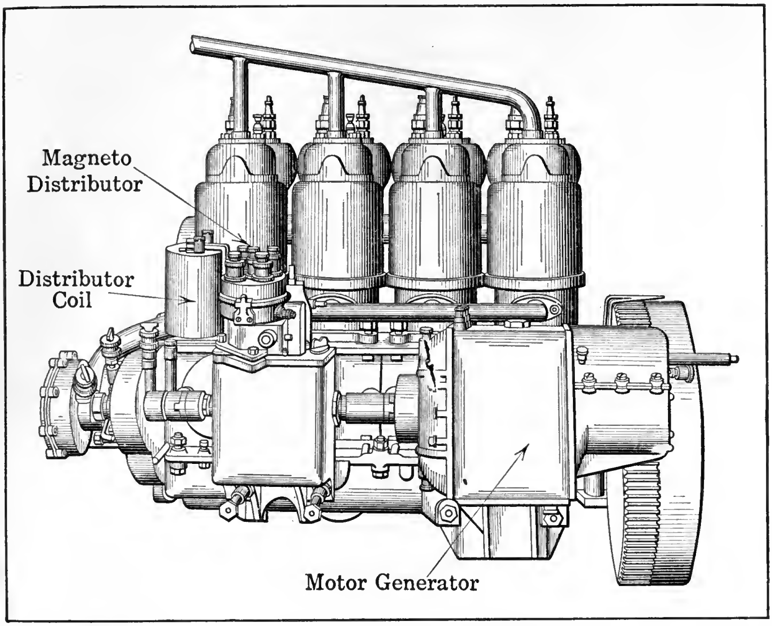


Fig. 341.—Motor Generator Employed in Starting Cadillac Motor also Furnishes Current for Ignition and Lighting.

When it is desired to start the engine an electrical connection is established between the storage battery and the motor-generator unit, and this acts as a motor and turns the engine over by suitable gearing which engages the gear teeth cut into the engine fly wheel. On the Cadillac car the motor generator furnishes current for ignition and lighting as well as for starting the motor, and the fact that the current can be used for this work as well as starting justifies to a certain extent the rather complicated mechanism which forms a complete starting, lighting, and ignition system.

Summing up the advantages of these various self-starters, it would seem that in most cases very satisfactory results could be obtained from the forms in which acetylene gas is introduced to the cylinders and then ignited by turning on the switch. These ignition starters have a disadvantage, however, that they cannot be used where ignition is by magneto without battery auxiliaries. Starters which rotate the crank shaft have the advantage that they can start a motor even if it is equipped with a magneto because they will turn an engine over faster than is possible by hand power, and the result is that a spark of adequate strength will be generated to ignite the gas even if batteries and coil are not provided.

The disadvantage of air-starting systems is that the air chills the cylinders and makes starting somewhat difficult in cold weather or when conditions are such that the gasoline mixture is not properly proportioned. If considered merely from the point of view of results obtained, it would seem that the electric starter with its capacity for a large number of motor starts per charge of batteries would be the most suitable form. As previously stated, however, its mechanical complication is a strong enough disadvantage that many consider it of sufficient moment to outweigh the advantages of the system.

Motor-Car-Lighting Systems.—When the automobile was first invented it was a comparatively slow-speed conveyance, and ordinary oil lamps such as used on carriages or bicycles for illuminating the roadway at night proved adequate for the newer form of conveyance. As cars have become improved it was found necessary to provide stronger radiants than kerosene lamps to illuminate the roadway because of the greater speed capabilities of the improved automobile.

In order to provide higher illuminating powers than would be present by using kerosene alone, the kerosene lamps were supplemented by search lights supplied with burners designed to burn acetylene gas. Two methods of furnishing acetylene gas to the burners are in use, one being to use some form of generator which makes the gas as it is needed, the other is to take the gas required from some container where it has been stored under pressure.

The usual form of generator employed in connection with gas lamps is shown at Fig. 342, A. The acetylene gas is generated by combining water with calcium carbide, the latter being a mixture of coke and lime which has been fused together in an electric furnace. Pure calcium carbide will produce about 5.5 cubic feet of gas per pound of carbide decomposed, but the commercial product seldom yields more than 4.5 cubic feet. Acetylene is a very brilliant illuminating gas and gives a white light of about 240 c. p. if burned at the rate of five cubic feet an hour. The strength of illumination can be better judged by comparing it with that produced by burning five cubic feet of good coal gas in the same period of time which will only result in 16 c. p.

A special form of burner is used in the automobile headlight, which mixes a certain amount of air with the gas and the brilliant white light produced is intensified and projected by means of a lens mirror placed at the back part of the lamp. This lens serves to collect and concentrate the rays of light from the flame into a beam composed of parallel rays which have great illuminating power, and which will light up the road for hundreds of feet ahead of the car and permit higher speeds with safety than would be possible with the feeble glimmer of oil lamps.

The generator employed and its mode of action may be easily understood by referring to Fig. 342, A. It consists of a water tank and separate compartments for carbide and gas and a filtering chamber. Water is dropped on the carbide and as soon as the two come in contact the chemical begins to decompose and acetylene gas is liberated while lime dust collects in the bottom of the generator as a residue. The gas collects in a reservoir and forces its way through a filter chamber filled with wool or similar material which filters the gas. The gas is also cooled before it reaches the lamps because the gas outlet pipe and filter is surrounded with water.

When the shut-off valve is opened it permits the water which has collected in the intermediate chamber to drop into the carbide basket through a perforated tube. If the pressure in the intermediate compartment is normal atmospheric pressure, the water will drop freely onto the carbide until considerable gas is liberated. Just as soon as the gas generated has an appreciable pressure it flows into the intermediate chamber and prevents more water reaching the carbide until the gas pressure is lower. The generator will continue to supply gas as long as the supply of water and carbide lasts.

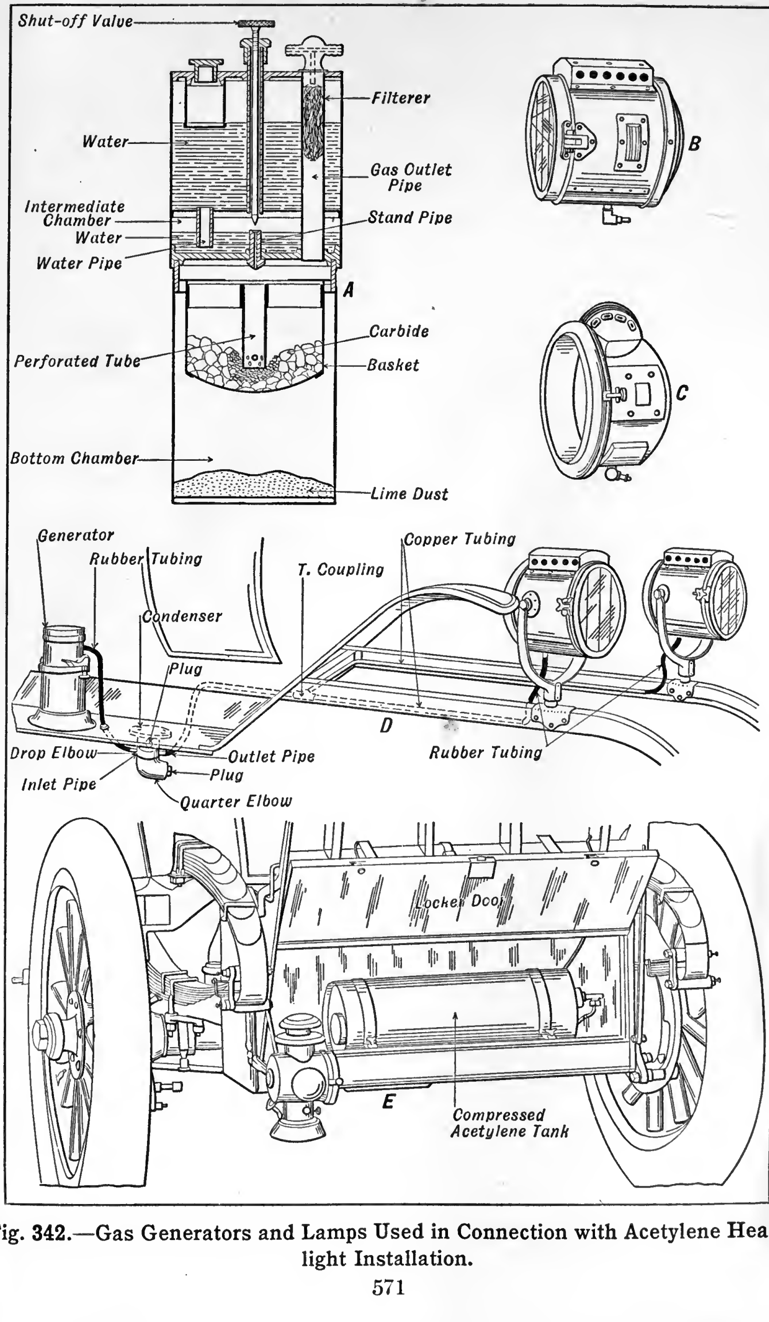


Fig. 342.—Gas Generators and Lamps Used in Connection with Acetylene Headlight Installation.

The forms of lamps used are shown at Fig. 342, B and C, and the method of installing a generator and lamp outfit is clearly outlined at D. The headlights are usually placed at the front end of the frame where they are carried by suitable brackets or yokes, and connection with the generator is made by lines of copper and rubber tubing which convey the gas from the generator to the burner. A trap is sometimes interposed between the generator and the burners to arrest any foreign matter or moisture that may have passed through the filtering material in the gas outlet pipe.

The method of installing a compressed acetylene storage tank sometimes used to supply the gas instead of the generator shown at E has advantages in that the tank may be easily reached when it is desired to replace it, and at the same time it is out of sight and not liable to become damaged. When the construction of the car does not permit the use of a separate locker for the gas tank this member is often carried on one of the running boards of the car.

When acetylene lamps are used they are usually supplemented by a set of oil lamps which are provided at the sides of the dash and as a rear signal; while the kerosene lamps do not give much light they are dependable in every way because they are very easy to understand and require no care except an occasional trimming of the wicks and filling with kerosene. If the acetylene lamps did not function properly the kerosene flames would provide sufficient illumination so that the roadway immediately in front of the car would be lit up enough to detect obstacles, and at the same time the lamps would act as a warning signal to other users of the highways. Kerosene lamps are also useful for city driving where the intense glare of the acetylene lamps would be annoying. The usual motor-car lighting system consists of two headlights, burning acetylene gas, two dash lamps, and one tail light burning kerosene.

If a gas generator is kept clean and properly filled with carbide and water there will be no trouble in obtaining adequate supplies of gas. While burners sometimes clog up it is a very easy matter to clean out the openings with a fine piece of wire or to supply a new burner if the defective one cannot be repaired.

Electric-Lighting Systems.—During the past year many manufacturers have employed electric lamps to advantage on automobiles, and while these were formerly fitted only to the high-grade cars the development made in providing suitable current producers and lamps having strong filaments has made possible the application of electric lighting to all classes of cars. The usual method of current supply is by storage battery, somewhat similar in principle to those used for supplying ignition current but which are more substantially constructed and have plates of greater capacity than those usually pro-

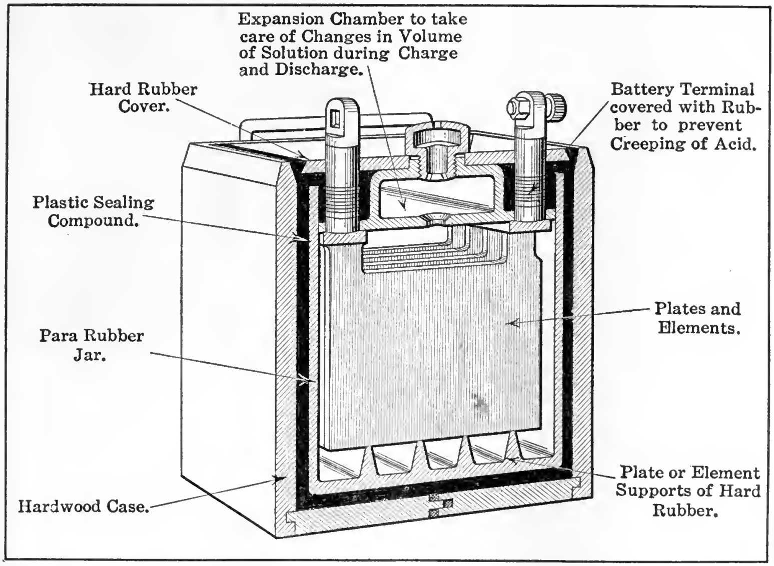


Fig. 343.—Special Storage Battery Employed to Furnish Lighting Current.

vided in ignition cells. The construction of a typical lighting battery is shown at Fig. 343, this form having been designed especially for this class of work.

Mechanical generators of electricity are also used in various forms, and a number of small dynamos have been used successfully in connection with a storage-battery system. When a dynamo is provided it usually supplies its current directly to a storage battery, and the electricity for lighting is taken from the storage battery rather than the dynamo. The reason for this is that any fluctuation of engine speed makes the current production vary in value. If the engine was running slow and the lamps were attached directly to the generator there would not be sufficient illumination. At the other hand, if motor speeds were high and the generator was driven faster, enough current might be produced to burn out the lamps. When the current from the dynamo is directed to a storage battery that member serves as an equalizer and will maintain a constant discharge to the circuit in which the lamps are wired. It will absorb

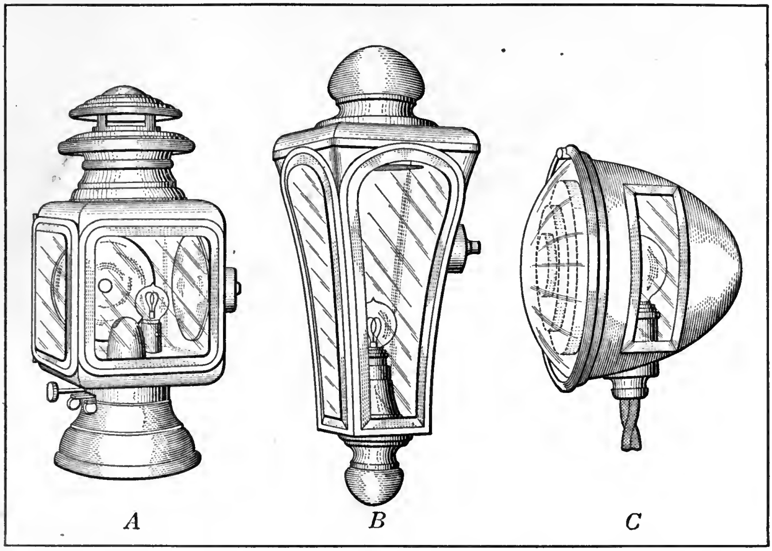


Fig. 344.—Side and Tail Lamps Using Electric Bulbs for Illumination. A—Kerosene Side Lamp with Tungsten Lamp in Corner. B—Pillar Lamp for Limousine Bodies Uses Electric Lamp Exclusively. C—Small Electric Tail Lamp.

excess electricity generated at high-motor speeds and will supply that energy to the lamps at such time that the generator would be inadequate to supply the proper amount of current.

Various forms of lamps utilizing electric bulbs are shown at Figs. 344, 345, and 346. Those at A, Fig. 345, are side lamps that have been designed especially for use with electric current, while those depicted at B are combination forms in which the electric light bulb has been inserted in an oil lamp of conventional pattern in such a way that it will not interfere with the normal operation of the kerosene burner should it be desired to use the kerosene flame. This feature is one that provides an important advantage in that a failure

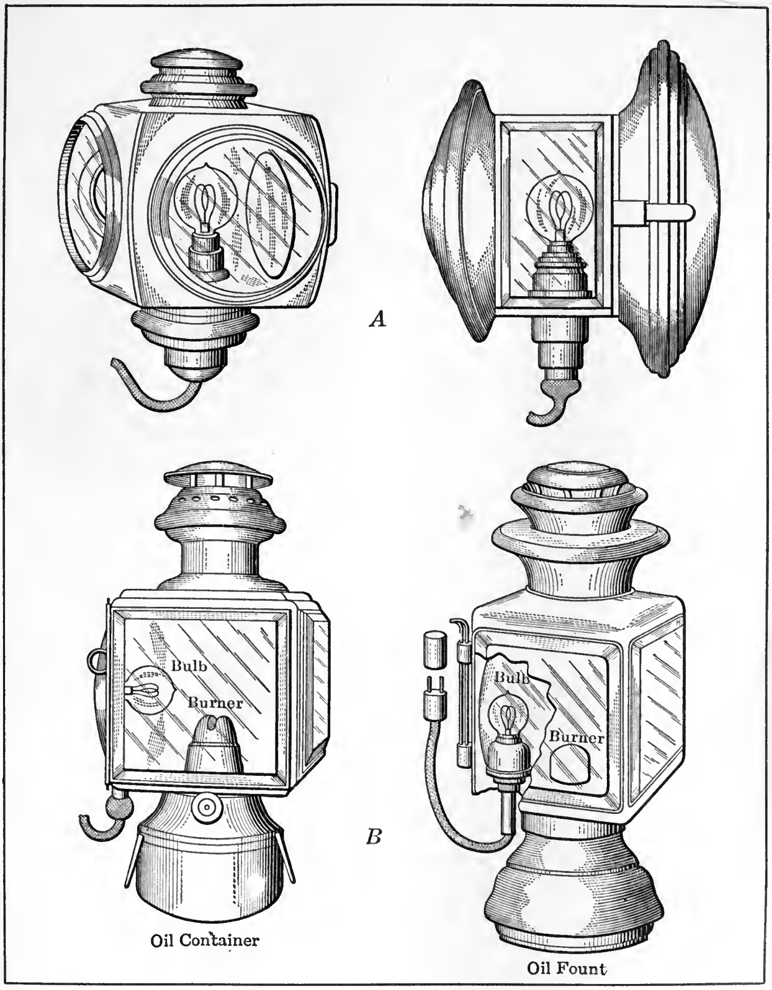


Fig. 345.—A—Side Lamps Designed to Use Only Electric Bulbs. B—Methods of Combining Kerosene Burner and Tungsten Bulb in Side Lamps.

of the electric lamps or source of current would not seriously inconvenience the motorist, as he could use the kerosene burner and secure adequate illumination to enable him to operate the car without danger. The combination shown at Fig. 346 shows the adaptability

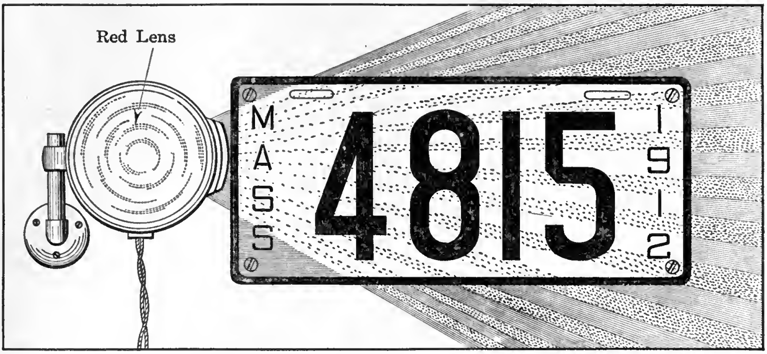


Fig. 346.—Gray & Davis Combined Electric Tail Lamp and License Plate Holder, a Device of Marked Utility.

and simplicity of the electric light to good advantage. In this the electric lamp is mounted in connection with a license number in such a way that a stream of white light is thrown on the number to illuminate it, whereas a red lens shows a danger signal to the rear.

The most important component of the modern electric lighting system, and one that has made electric lighting practical, is the incandescent lamp. This produces light because a filament of conducting material becomes heated by the passage of electric current and gives off rays when it is in an incandescent condition. The electric bulbs used in automobile lighting systems have tungsten filaments instead of the carbon members formerly widely employed in lamps used for house lighting. The tungsten filament gives a more intense and concentrated light than the other forms, and its current consumption is much lower. The filament is stronger and more enduring as it is not liable to be broken by vibration incidental to motor car use. An ordinary carbon filament consumes about 3.5 watts per candle power, while the tungsten loop uses but 1.25 watts to provide the same degree of illumination. The economy of the tungsten filament is of special importance if the current used for lighting is derived from a chemical source, and even if a mechanical generator is used this can be made lighter and more compact and require less power to drive it than if ordinary carbon filament lamps of equivalent candle power were used.

The types of lamps and bases used are shown at Fig. 347. The bulb shown at A has a cluster-loop filament and an Edison screw base. The lamp is screwed into a suitable threaded socket and the circuit is completed when the stud on the lamp bottom makes contact with a suitable contact spring in the socket. The objection advanced against the Edison screw base is that this may be loosened by vibration, and as soon as the lamp becomes loose and the button at the bottom leaves a contact spring the circuit will be interrupted and the light go out. The continued vibration may cause the lamp to work out of the socket and become broken.

Many motorists favor the Edi-Swan method of bulb retention. In this the lamp base is plain and is provided with a couple of small locking pins. A special slotted socket is used and when the lamp is

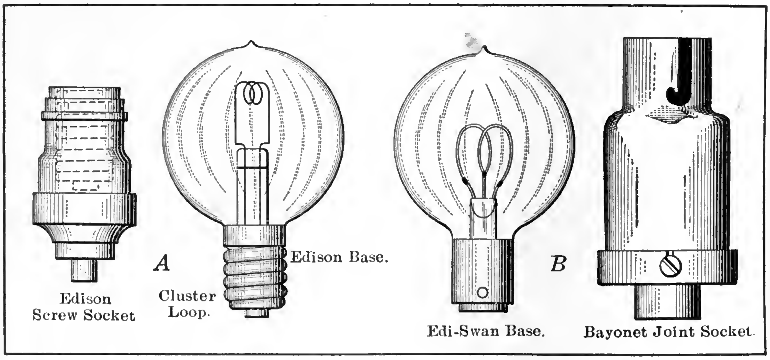


Fig. 347.—Incandescent Bulbs and Sockets Used in Motor-Car Lamps.

put in place it depresses a strong spring that makes contact and which also locks the lamp firmly in place when it is given a quarter turn, so the pins fit into small depressions at the side of the main slot. This form of lamp cannot jar loose and it is easily inserted or removed from its socket. The object of using a short and thick filament of the cluster-loop type is to provide for secure anchorage of the leading in wires, and at the same time to provide a more intense and concentrated light, which is better adapted for use with the forms of reflectors where the lamp must be at the correct focal point to secure proper projection of the beam of light.

When an electric-lighting system is provided the current can be adapted to other uses besides merely providing illumination of the roadway. Small fixtures used for illuminating the speedometer, oil gauge or clock may be easily brought into use by merely pressing a push button located at some convenient point. The interior of

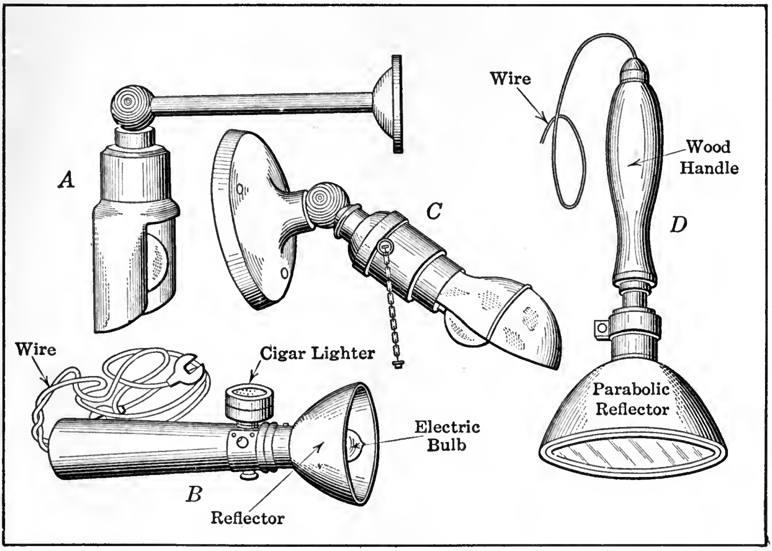


Fig. 348.—Convenient Electric Fixtures That May Be Included in Equipment of Cars Using Electric Lighting Systems.

limousine bodies may be brightly illuminated, and other conveniences in the form of trouble lamps and cigar lighters may be used to advantage. Some of the special forms of lamps are shown at Fig. 348. That at A is a small dash fitting designed to throw the light from the lamp directly against the face of a clock or speedometer. A useful "trouble lamp" which combines a cigar lighter as well is shown at B. The bulb is mounted in a special reflector attached to a suitable handle which is connected to the source of current by a long, flexible wire cable which permits the lamp to be used at all points

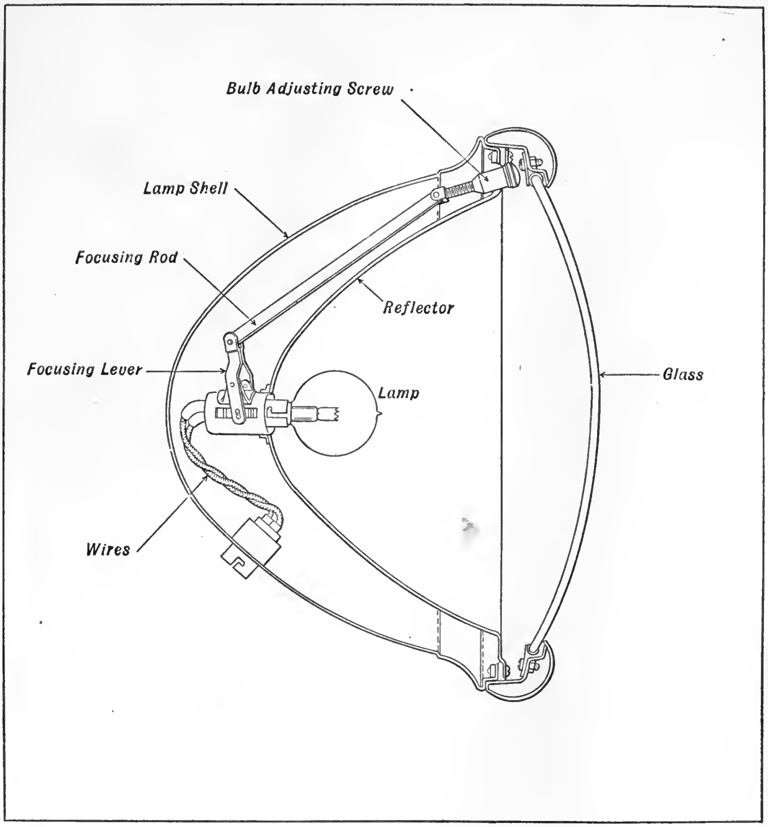


Fig. 349.—Sectional View of Gray & Davis Electric Headlight Showing Method of Focusing Bulb by Accessible Adjusting Screw.

of the car. The form shown at C is a modification of the dash type depicted at A and is used as a side bracket for interior illumination of closed bodies. The search light illustrated at D is a modified form of that shown at B and does not combine a cigar lighter.

An electric headlight of very good design is shown at Fig. 349.

The lamp is mounted in a movable base that may be adjusted so the bulb will always be in the proper relation to the parabolic reflector to throw an intense beam of light. As will be evident the construction of such a lamp is simple and makes possible smooth forms, which are much neater appearing than gas lamps if only the electric filament is used for illumination.

Many automobilists are inclined to be suspicious of innovations, and because of their familiarity with kerosene oil and gas lamps they

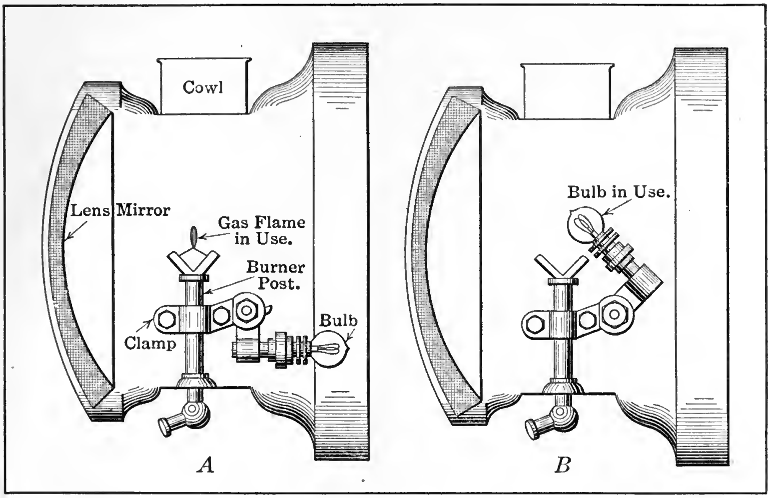


Fig. 350.—Combination Headlight Fitted with Both Gas Burner and Electric Bulb. A—Position of Bulb with Gas Flame in Use. B—Bulb Furnishing Light.

desire to retain these and use the electric bulb as well. This is easily done in the case of side lights by putting in a bulb at some point where it will not interfere with the regular burner. Gas burning headlights may be converted to use electric current when desired by simple adapters as depicted at Fig. 350. These are clamp members attached to the burners. A lamp socket is mounted in such a manner that it may be swung out of the way as shown at A, when it is desired to use the gas flame or moved back so that it occupies about the same position relative to the lens mirror as does the gas flame

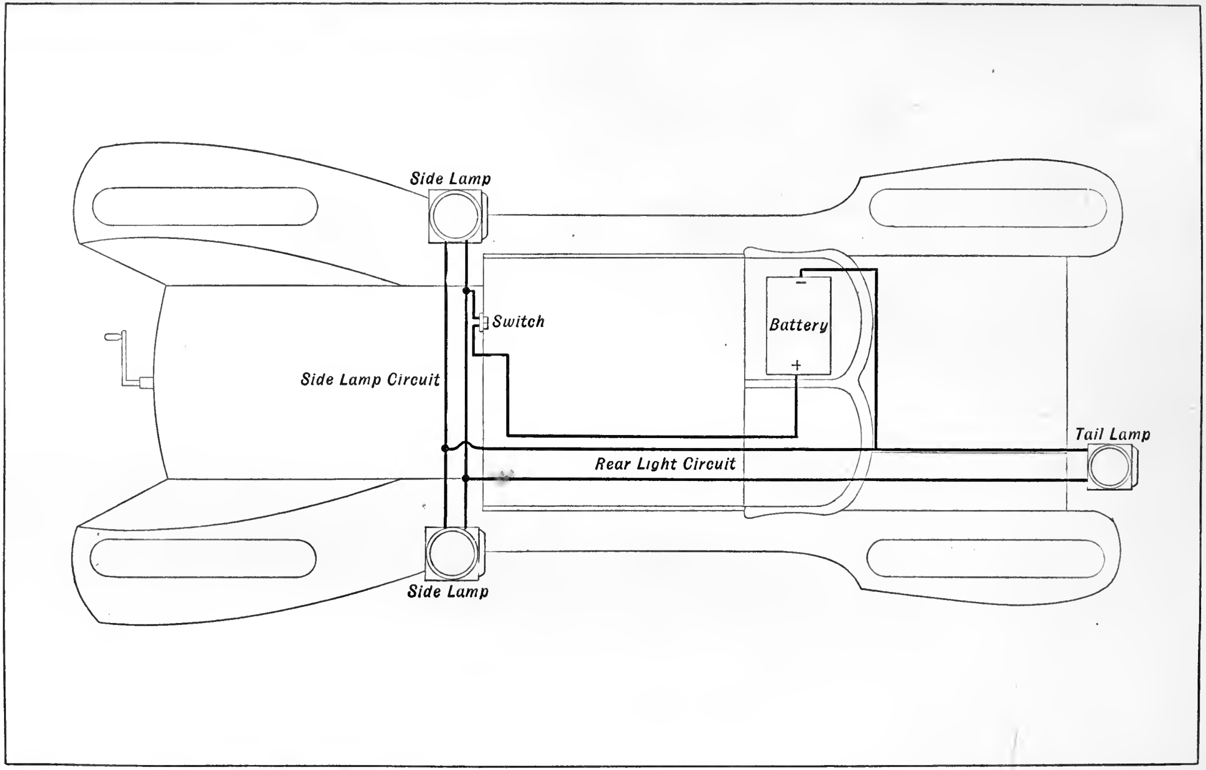


Fig. 351.—Wiring Diagram Showing Connections of Simple Three-Lamp Electric-Lighting System.

when electric light is desired. The position of the bulb at times it is desired to use electricity instead of gas is shown at Fig. 350, B.

A typical simple lighting system such as would be used on a light runabout or car employing acetylene gas search lights is depicted at Fig. 351. In this case the side lamps are provided with two- or four-candle-power bulbs, while a two-candle-power lamp will be found of adequate capacity for the tail lights. The current can be supplied either by a multiple series dry battery of at least twelve cells or a six-volt, sixty-ampere-hour storage battery. With this system the lamps do not consume any more current than would be provided by the normal discharge rate of an ignition battery and the same type of current producer used for ignition work can be applied to small electric-lighting systems without trouble. If lamps of higher candle power are used, which consume more current, it will be necessary to use a special lighting battery of about eighty ampere-hour capacity. The three lamps are controlled by a single switch and the method of wiring is so clearly shown that it can be easily followed by anyone desiring to install a simple electric-lighting system.

A more comprehensive lighting system such as would be used on a high-powered touring car is shown at Fig. 352. In this the headlights are provided with twelve- or sixteen-candle-power bulbs, the side lights with six-candle-power bulbs, the tail light with a four-candle-power lamp. The small meter light which is wired in series with the tail lamp is fitted with a one-candle-power filament. The current supply is by a dynamo and storage battery which delivers a current of about twelve volts pressure. An automatic switch is provided so the dynamo will supply current to the battery only when it is being run at sufficient speed to insure the delivery of a proper amount of electric current. The current for the lamps is taken from the battery which is kept charged by the dynamo. A three-unit switch is provided with buttons controlling three circuits. One of these is the headlight group, the side lamps are on another circuit, and the tail lamp and meter light are controlled by an individual switch. The object of putting the meter light in series with the tail lamp is to furnish indication to the operator if the tail-light bulb should burn out. If the meter light is out the tail light will go out

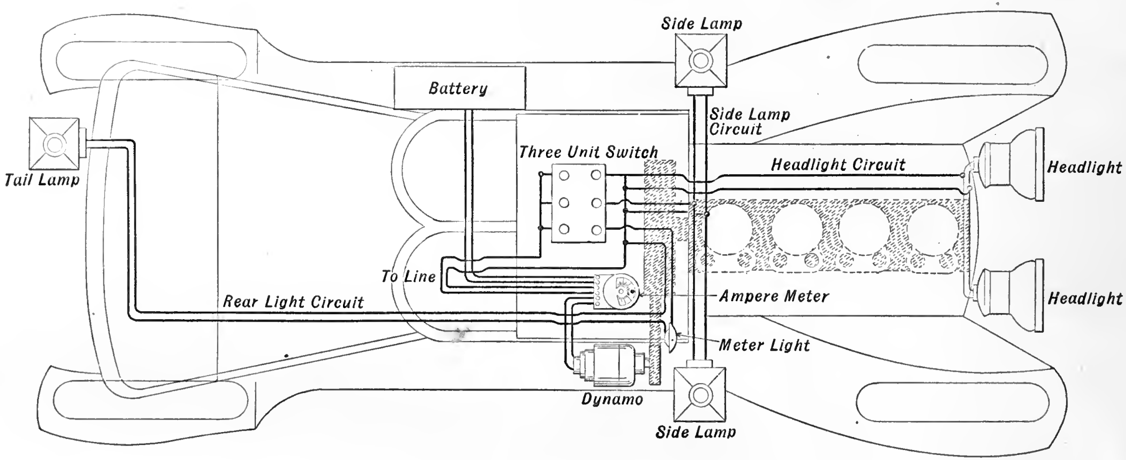


Fig. 352.—Complete Six-Lamp, Three-Circuit Electric-Lighting System with Mechanical and Chemical Current Producers.

also and vice versa. As is true of the group at Fig. 351, the wiring diagram may be easily understood and will be useful as a guide for the installation of a complete electric-lighting equipment.

Utility of Wind Shields.—One of the items of equipment that conduces to comfort of the occupant is the wind shield. In winter this member serves to deflect the cold wind and provide a transparent shelter for those behind it while in summer it is useful in screening the eyes when driving on dusty roads. Wind shields are made in many

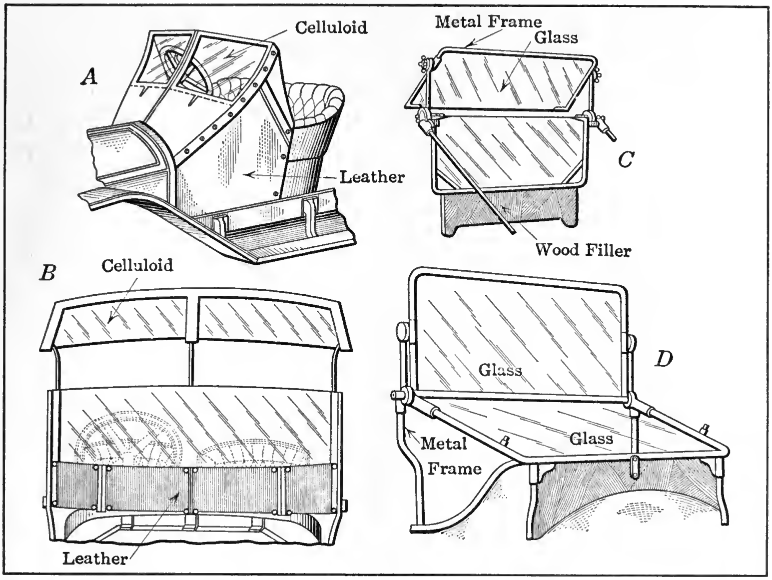


Fig. 353.—Conventional Wind-Shield Forms.

forms, though the usual materials employed are celluloid and leather or wood, metal, and glass in combination. Typical wind-shield forms are shown at Fig. 353. That at A consists of a metal frame covered with leather and provided with transparent celluloid windows. Side curtains extend from the frame to the sides of the seats and the passengers are completely protected. Another form of celluloid and leather wind shield is shown at B. This differs from the form previously described in that it is vertical, whereas that shown at A is inclined at an angle and will offer less air resistance than the forms which are at right angles to the frame-side member. The advantages of using celluloid are that it is lighter than glass and that it is not liable to become broken. The disadvantage to its use is that it will crack very easily and cannot be looked through as easily as the less opaque glass.

Glass wind shields are usually composed of a frame of brass tubing in which large panes of plate glass are set. The frames are usually constructed with joints so the top portion of the wind shield may be swung down out of the way when it is not needed. The metal frame which carries the glass is set on a wood filler piece of such form that it will fit the dash, and the whole assembly is braced by means of rods extending from the lower frame to the front or sides of the car, as shown at Fig. 353, C and D. Wind shields are an indispensable item of equipment and no automobile can be considered complete without this useful means of protection.

Function of Shock Absorbers.—Even when the springs of automobiles have been very carefully selected with reference to the loads they are to sustain, as previously stated, it is difficult to make provision for the many variations in loads and speed of the vehicle. A car that will be very easy riding on good roads will be uncomfortable on rough highways because the light springs jounce the occupants around if the car is operated at anything except slow speed. In order to provide smooth riding it is customary to select springs that are a compromise and that will not be too hard riding on good road surfaces and yet will not move unduly when the car is run over rough roads.

Various forms of shock absorbers have been devised to supplement the action of the vehicle springs. These may be in two forms, those designed merely to receive shocks caused by sudden spring deflections and other appliances devised to check excessive motion of the springs by providing a dampening action. The simplest form of shock absorber is shown at Fig. 354, A. This is designed for use with springs which are too flexible and which may settle down if the car is loaded to its capacity. A rubber buffer is carried by a clip piece extending under the spring clips to hold the rubber pad in place. An angle bracket is riveted to the frame-side member if the spring is hung outside of the frame, and this carries a bolt which engages with a rubber bumper to stop excessive movement of either frame or spring.

An auxiliary spring designed to work in conjunction with the main supporting members is shown at Fig. 354, B. This is a heavy coil spring carried inside of the frame member, one end being attached to a forging bolted to the frame side and the other to the

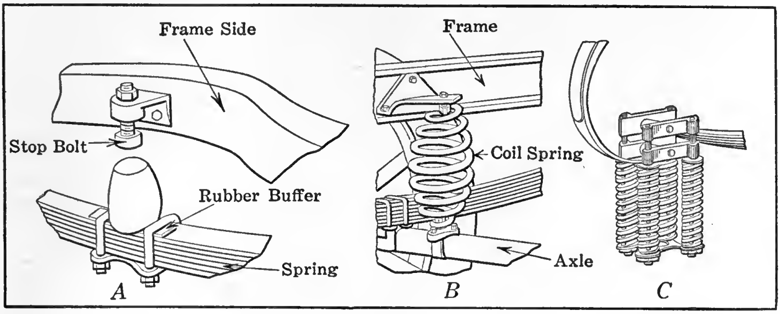


Fig. 354.—Methods of Promoting Easy Riding of Automobiles Supplied with Inadequate Springs.

axle. Such a spring will not interfere with small spring deflections, but it will prevent excessive motion of the frame or axle either on spring depression or rebound. When springs are so stiff that they will not yield readily to the minor inequalities of the road surfaces it is customary to provide some form of auxiliary spring as shown at Fig. 354, C. A spring of this nature replaces the usual shackle or link, and the small coil springs will yield readily to obstacles that would make no impression on the stronger leaf spring.

Shock absorbers that act by producing a dampening effect to check spring movement are shown at Fig. 355. The simplest of these comprises a pair of levers hinged together at one extremity and attached to the frame and spring, respectively. The form shown at A has a friction pad between the two portions at the hinge and this member provides the dampening effect desired. The form shown at B is somewhat different in principle. One of the levers is cup shape while the other carries a cam. A number of steel springs are inserted in the cup and excessive movement of either frame or axle is prevented by the friction effect of the three-point cam on the three compound leaf springs inside of the cup.

Many other forms of shock absorbers have been devised, some consisting of cylinders filled with oil and having a piston to act as a check to prevent too rapid movement of a plunger rod working in the cylinder. One member would be secured to the axle and the other to the frame. Many makers furnish shock absorbers as an item of regular equipment, and if a car which is not equipped with these members does not ride as comfortably as desired the spring action may always be improved by installing some form of shock absorber best adapted to meet the conditions. Springs that are too flexible should either have their action dampened or should be provided with some auxiliary buffer. Hard riding springs can be improved by the use of auxiliary cushion springs as shown at Fig. 354, C.

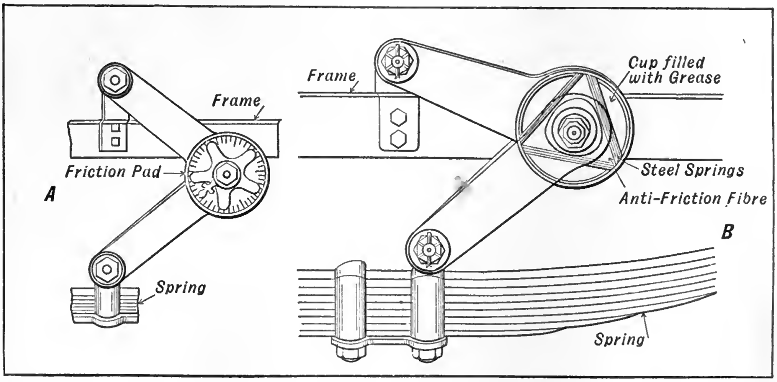


Fig. 355.—Efficient Shock Absorbers That Improve Spring Action on Rough Roads. A—Truffault-Hartford with Friction Pad. B—Connecticut Device Moves Cam Against Spring Resistance.

Signals and Alarms.—The laws of most commonwealths make it imperative for the motorist to equip his car with some form of warning signal that will be adequate to advise other users of the highway of the car's approach. Many forms have been devised ranging from simple reed horns operated by hand pressure on a small rubber bulb to more complex alarms in which an electric motor serves to actuate a diaphragm and produce a noise that can be heard for a long distance.

A combined hand- and electrically-operated signal is shown at Fig. 356, A. An ordinary form of bulb-operated reed horn is attached to the sound intensifier of an electrically operated signal. The object

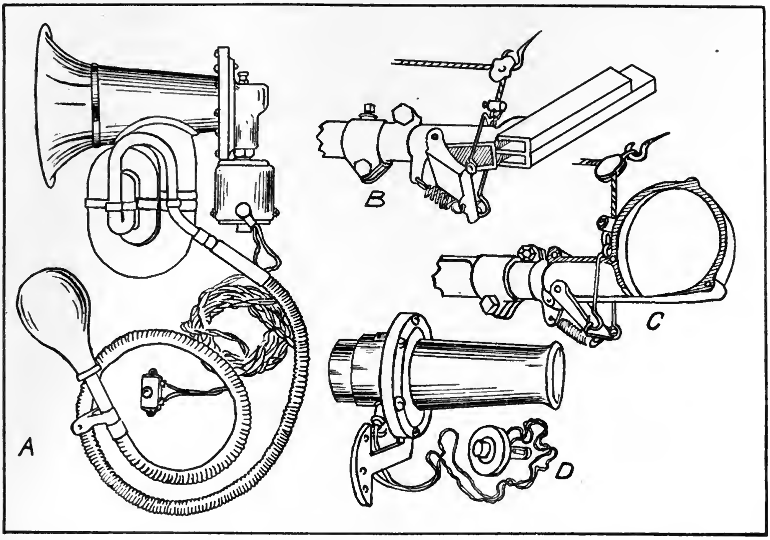


Fig. 356.—Forms of Motor-Car Alarms That Give Satisfactory Service. A—Combined Klaxon Signal and Bulb Horn. B and C—Exhaust Whistles. D—Electrically Operated Signal.

of combining the two alarms in one is to provide a hand-operated alarm for ordinary driving, while the louder electrical signal is employed when the sound must be heard for a considerable distance.

The signals shown at B and C are operated by the exhaust gases and are attached to the end of the exhaust pipe. They are operated by depressing a small foot pedal on the foot board, and various sounds may be produced from a mellow note to a shrill whistle depending upon engine speeds. The alarm shown at D is operated by electrical means and the diaphragm is actuated by a small electric motor which will run from the storage battery usually employed for ignition purposes. The advantage of the electrically operated signals that makes them popular is apparent. The push button may be attached to the steering wheel convenient to the driver's hand and the signal may be obtained by a simple pressure of the finger, which is sufficient to close the circuit and actuate the apparatus which produces the sound.

Speed-Measuring Devices.—When one considers the stringent laws of most communities regulating the speed of motor vehicles it will be evident that some form of speed-indicating device is necessary to show the velocity at which the car is traveling at any time. Speedometers are usually combined with odometers or mileage counters, and it is not uncommon to provide a clock as well. A speedometer has other uses besides merely indicating the rate of travel. It forms an excellent indication of the value of different carburetor adjustments and it enables the motorist to compile definite figures regarding fuel and oil consumption or tire depreciation for a given period of time.

Various speedometer forms are shown at Fig. 357. That at A is a simple instrument to indicate the speed and distance. The type depicted at B indicates the total distance traversed and the number of

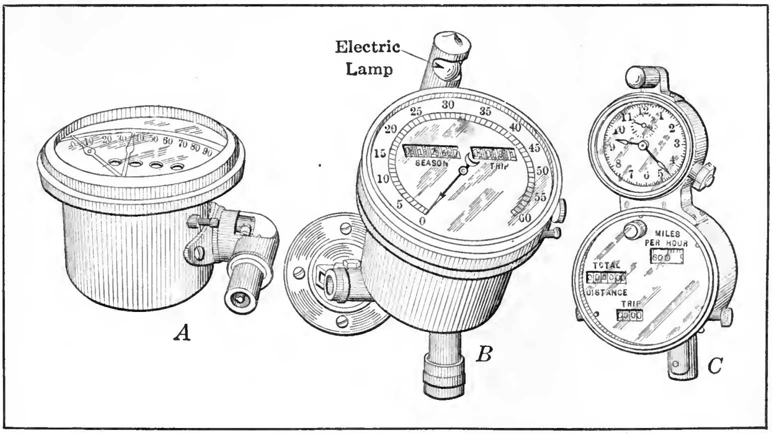


Fig. 357.—Speedometers Useful in Indicating Speed and Mileage.

miles covered on each trip as well as the speed. It is provided with a small electric lamp at the top to illuminate the dial at night. The speedometer shown at C has all of the features of the other two instruments with the added one of having a clock to indicate the time. Speedometers are usually placed on the dashboard of the car and are driven from the front wheels by means of suitable reduction gears mounted on the steering knuckle and a flexible shaft.

Speed indicators may operate on different principles, some depend on magnetism, or the flow of liquids, others utilize centrifugal force and operate just the same as the fly-ball governor of an engine, An instrument which depends upon the principle of centrifugal force to indicate speed is shown in section at Fig. 358. The driving

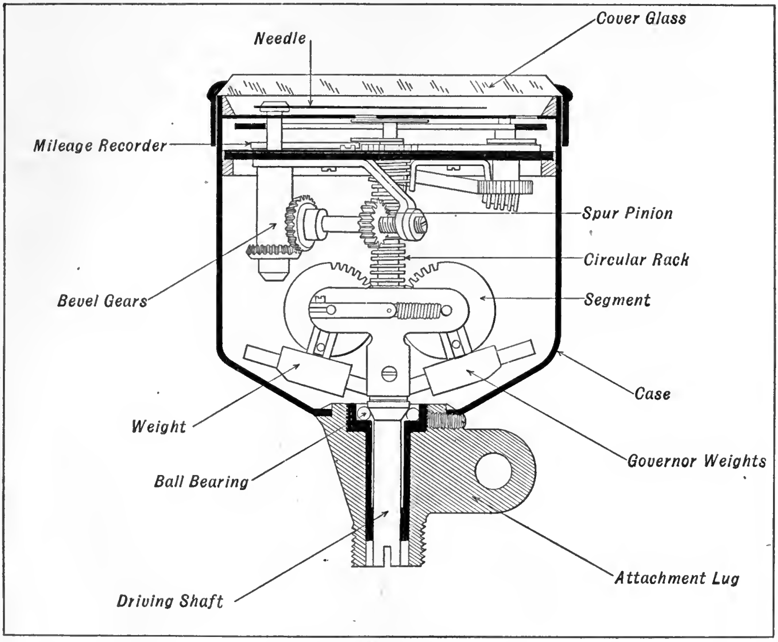


Fig. 358.—Sectional View of Speedometer Which Depends on Centrifugal Force Stored in Governor Weights to Actuate Indicating Needle.

shaft carries a pair of weights which are thrown out as the speed increases. These weights swing a pair of segments meshing with the circular rack and impart an up and down reciprocating motion to this member as they revolve. The circular rack meshes with a small spur pinion and its reciprocating motion is converted to an oscillating one by means of the pinion. A pair of bevel gears transmit the motion of the spur pinion to the speed-indicating needle at the top of the apparatus. The weights and their position are so calculated that as the speed increases they fly out from center and pull down the circular rack. This, in turn, moves the spur pinion and bevel gears, and causes the needle to register the speed corresponding to the position of the governor weights.

A small train of gearing similar in principle to that used in a bicycle cyclometer is carried between the speedometer case and the dial, and serves as a distance-recording gauge. The driving shaft to which the governor weights are attached is driven by a flexible shaft connecting to one of the front wheels in the conventional manner. It is contended that speedometers which depend on centrifugal force are more accurate under all conditions than those utilizing either magnetism or the flow of liquids to indicate the speed. Those who favor the magnetic principle advance the contention that instruments of this character are more sensitive and will register low speeds more accurately than instruments depending upon centrifugal force. All of the many forms on the market have been used with success, however, and any speedometer of a reputable make is certain to furnish satisfactory service. Some form of speed-indicating device should be installed on every car, and their obvious utility can be easily understood when one remembers that the amount of one fine for fast driving will pay for a very efficient speed-indicating and mileage-recording instrument.

Tools and Miscellaneous Equipment.—In equipping a car for the season's use many factors must be considered, as the character of the supplies and spare parts required will vary with the type and make of car, while the tools needed for repairing the mechanism will depend largely upon the mechanical ability of the car owner or the person in charge of the automobile. While a very complete outfit of tools and spare parts would be the best insurance against trouble, it should be remembered that the weight of the tool outfit should be kept to as low a point as possible. As a general rule comparatively few well chosen tools that would be apt to be used often would be superior to an indiscriminately selected bulky outfit by one who has no knowledge of the value of the various appliances or how to use them. In modern motor cars it is easy to find storage room for a very complete assortment of tools and supplies, and while some of these may be considered unnecessary there may be a time when it will be invaluable especially if much touring is contemplated.

The first point to consider is selecting the common tools that one would be apt to need and as a guide a very complete tool roll such as sold by practically all automobile supply houses at a moderate price is shown at Fig. 359. The choice of a container for tools and supplies is very important and while the tool roll depicted, which is made of heavy canvas or leather, is very useful it has the disadvantage of being inconvenient to handle. As it must be unrolled every time certain of the tools would be needed, the ground is usually the only available place for its extension and the contents and casing may become very dirty. The writer prefers to use a tool box in which a number of trays are fitted. These are divided into compartments, each tool having a distinct space and to insure against rattle or injuring the tools the various compartments may be lined with felt or heavy cloth. A very good method of making the trays is to have these composed of or filled in with a wooden block, which is recessed to fit the tools to be carried. A container of this nature is superior to others as the tools needed most often can be placed in the uppermost tray, making them accessible, while in a roll the tools needed most often may be carried in the center. Some motorists throw the tools indiscriminately into a box and the result is that many of the appliances are damaged by coming in contact with other tools. The cutting edges of cold chisels and wire cutters are nicked, the teeth of files become broken or filled up with dirt, and screw driver points may become quickly blunted, and their utility reduced. At the same time the handles and polished surfaces of the other tools have become marred by the edges of the cutting tools.

The roll illustrated has a fair assortment of useful tools of good quality. The outfit consists of two screw drivers, two pairs of pliers, two chisels and one center punch, three drift pins, a set of four files, five wrenches, soldering copper and handle, a file handle, a split pin extractor, small roll of wire solder, two small rolls of wire—one soft iron and the other copper, small tin boxes containing extra split pins or locking cotters and lock washers, and a ball pein hammer. The wrenches include a set of three double open-end spanners, one adjustable monkey wrench, and a pipe wrench. Small and large screw drivers are provided and two pairs of pliers, one for handling

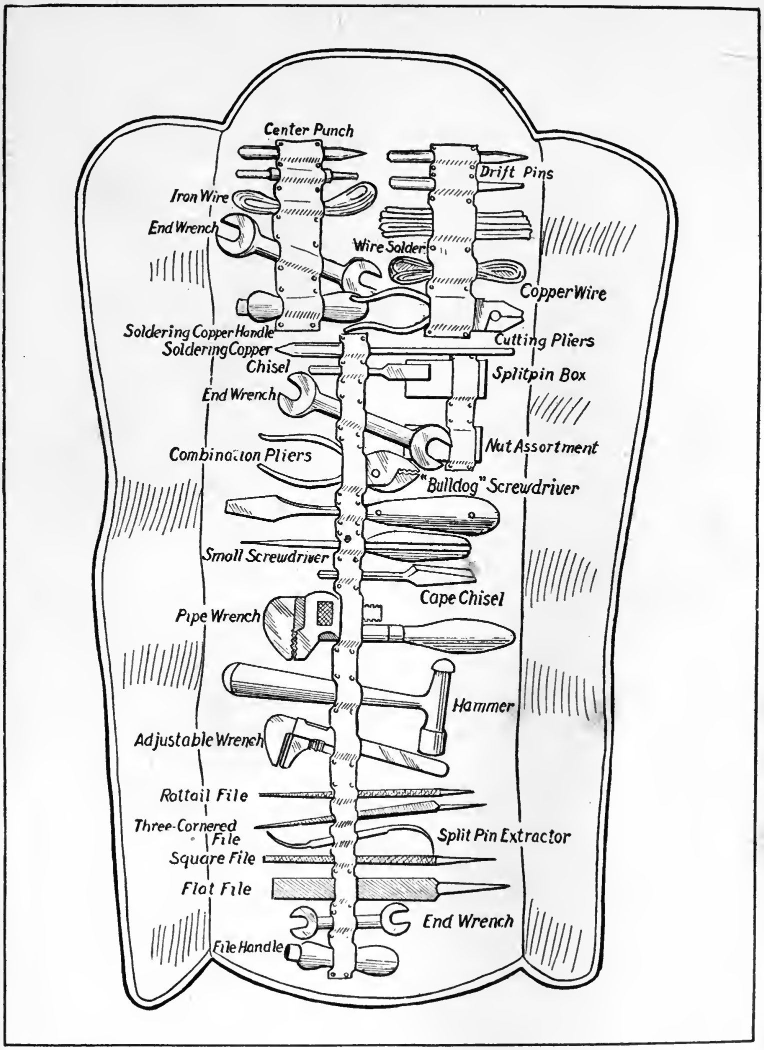


Fig. 359.—Tool Roll Suitable for Making All Ordinary Repairs on Automobile Mechanism.

flat pieces and cutting wire, the other for turning round pieces are included.

In addition to the tools shown in the outfit depicted at Fig. 359, a motorist who intends to make his own repairs will find those shown at Fig. 360 very useful. The valve-spring lifter is employed to compress the valve spring when it is desired to remove the locking key or washer from the bottom of the valve stem, and will be found very useful when the valves are to be removed for cleaning or grinding. The tinner's snips can be utilized to advantage in cutting sheet metal, packings, asbestos brake lining fabrics, stock for shims and many other purposes. The hack saw and a number of extra blades will be found of value when it is desired to cut bars of brass, steel, or iron, and it can be used in cutting wood, fiber, hard rubber, and other materials as well. The adjustable end wrench should be supplied in two sizes, a six inch for small work and one eight inches long for use on larger objects. This form of wrench is especially desirable for motor-car use as the opening between the jaws may be altered to suit requirements, and the angle of the head may be varied so it will work in some very inaccessible places where the ordinary forms of monkey wrench or open-end spanner could not be employed.

A complete file set is an almost indispensable part of the equipment and this should include members of square, round, triangular, and rectangular sections, in order to form various surface profiles needed on motor-car parts. The flat files are usually used for smoothing straight surfaces, and the round and half round are employed on curved pieces. The square file and the "three-square" or "three-cornered" file, as it is often called, are very useful in filing work where sharp corners must be left. In choosing files, one has almost as much latitude as in selecting other tools because they are made in various lengths and with different degrees of cutting power. In purchasing files, it should be remembered that the finer grades are used only for finishing, while those having coarser teeth are employed for roughing out work and removing metal. The file set should include in addition to the forms shown a small fine flat file, about the size of a manicuring file, for fine work on the platinum points of spark-coil vibrators or magneto-contact breakers. Files should be carried in cloth or leather cases or wrapped in heavy paper so

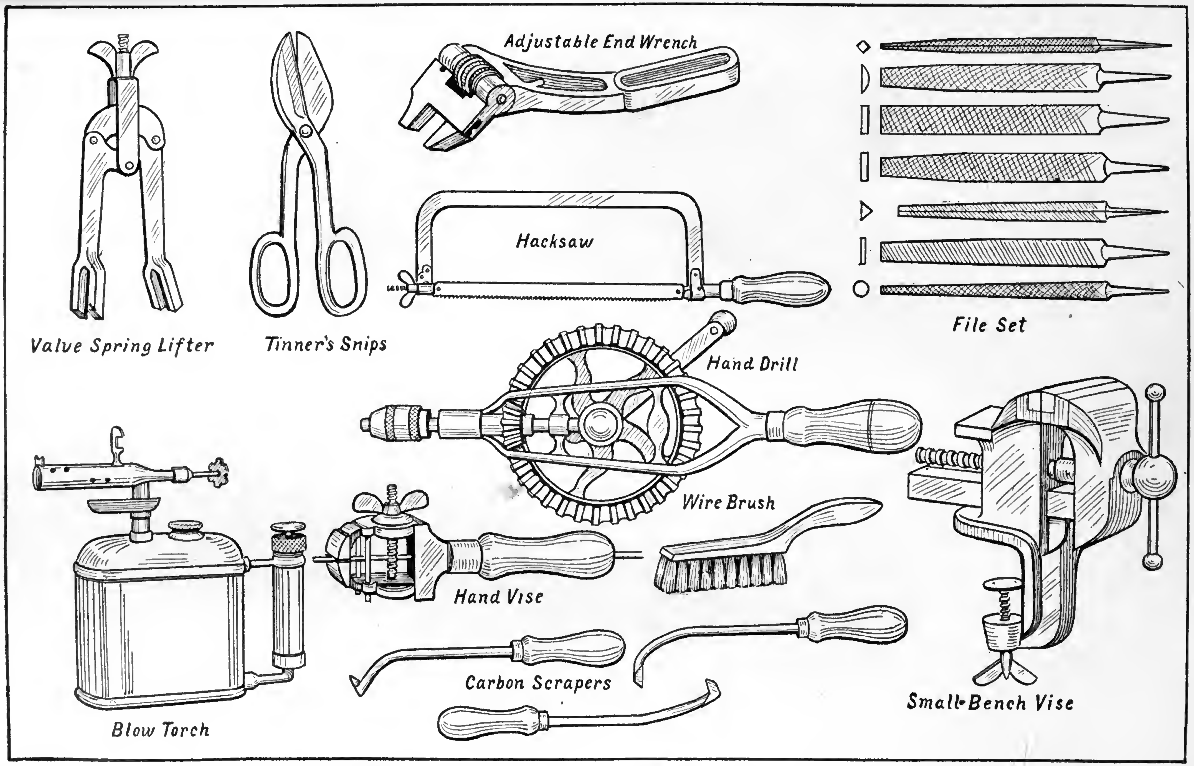


Fig. 360.—Useful Tools That May Be Furnished to Supplement Contents of Tool Rolls or Ordinary Small Tool Outfits.

that the cutting surfaces will be kept clean and away from other objects.

The gasoline blow torch forms part of the soldering outfit and can be used to advantage in heating the soldering copper. It is also useful in heating nuts or bolts that have become rusted in place, and as the flame is very hot the ends of small rods may be heated sufficiently so that they may be bent into eyes or rod ends very easily. A small hand drill with a number of common sizes of drills ranging from a No. 60 to about five sixteenths of an inch in diameter can be used so often in fitting small brackets, drilling holes in wood or metal, drilling out broken bolts or studs, and many other uses, that it will soon pay for itself. A wire brush is useful in tire work, where it can be used to roughen up the surfaces of the tube and patch before cementing or vulcanizing and for removing dirt, carbon, or solidified oil from the mechanism and for cleaning the teeth of files.

A set of carbon scrapers may be included with advantage in the outfit because these are formed in such a way that much of the carbon deposit that accumulates in the combustion chamber may be removed through spark plug and valve cage openings by their use without dismantling the engine. A small bench vise that can be clamped to the running board of the car is of value when filing or fitting pieces that could not be held properly with a pair of pliers. A small hand vise is also useful, as this will grip pieces of wire or sheet metal stock much firmer than a pair of pliers, and as the jaws can be clamped together by a winged nut no effort is required to hold the work, which is so securely held that it may be filed or hammered without dislodging it from the jaws of the vise.

In addition to the tools shown a lead- or copper-headed, or reënforced rawhide leather hammer may be included, as this can often be applied for driving bolts in and out without damaging the thread or for use against finished parts because it will not mar the surface. A set of socket or box wrenches and handle will be found useful in reaching bolt heads and nuts which are in inaccessible locations, and it is often desirable to supplement the two or three sizes of fixed spanners or S wrenches usually furnished in a tool roll by a number of other sizes which will permit one to handle practically all standard nuts. A set of five may be obtained that will fit all sizes of bolts from three sixteenths of an inch to one half inch, as ten milled openings are supplied which will handle bolt heads or nuts from three eighths of an inch to fifteen sixteenths of an inch in diameter.

A ratchet wrench that will fit the spark plug and one that will fit the nuts on the tire lugs have important advantages. With this form of wrench, after the box or end is placed over the nut of bolt head, it is not necessary to remove the wrench each time the handle is moved. The amount of movement permitted will vary with the conditions and sometimes will be only fifteen or twenty degrees. With a ratchet the handle is brought back to the starting point without moving the nut because the ratchet mechanism only holds in one direction. These wrenches are time savers wherever they can be used.

A word of caution to motorists who are apt to judge tools merely by the price should be heeded. Many men who are not mechanically informed select even the simpler tools by price rather than quality. As a rule the better quality tools only cost a few cents more and will give satisfactory service during a lifetime, while cheaper ones often cannot endure the work of a single season. Cheap chisels and punches are made of soft, improperly tempered steel; cheap wrenches are made from malleable iron castings, instead of steel drop forgings; low-priced screw drivers have the blades of inferior stock and so flimsily secured in the handle that they will turn on the slightest provocation instead of loosening the screw to which they are applied. The motorist who buys cheap tools is penny wise and pound foolish and it is better to purchase fewer tools, but good ones, if economy dictates when the purchase is made.

General Supplies and Spare Parts.—In addition to the tools enumerated there are many miscellaneous appliances that can be carried to advantage. Some of these are necessary only with certain types of cars, and many of the list which follows may be kept at home except when the car is taken on an extended tour which is apt to end at some distance from a convenient base of supplies. The group given at Fig. 361 has been selected because it shows many articles of equipment that have real value.

Funnels to fit the water, gasoline, and oil containers should be carried and it is well to use separate funnels for water, oil, and

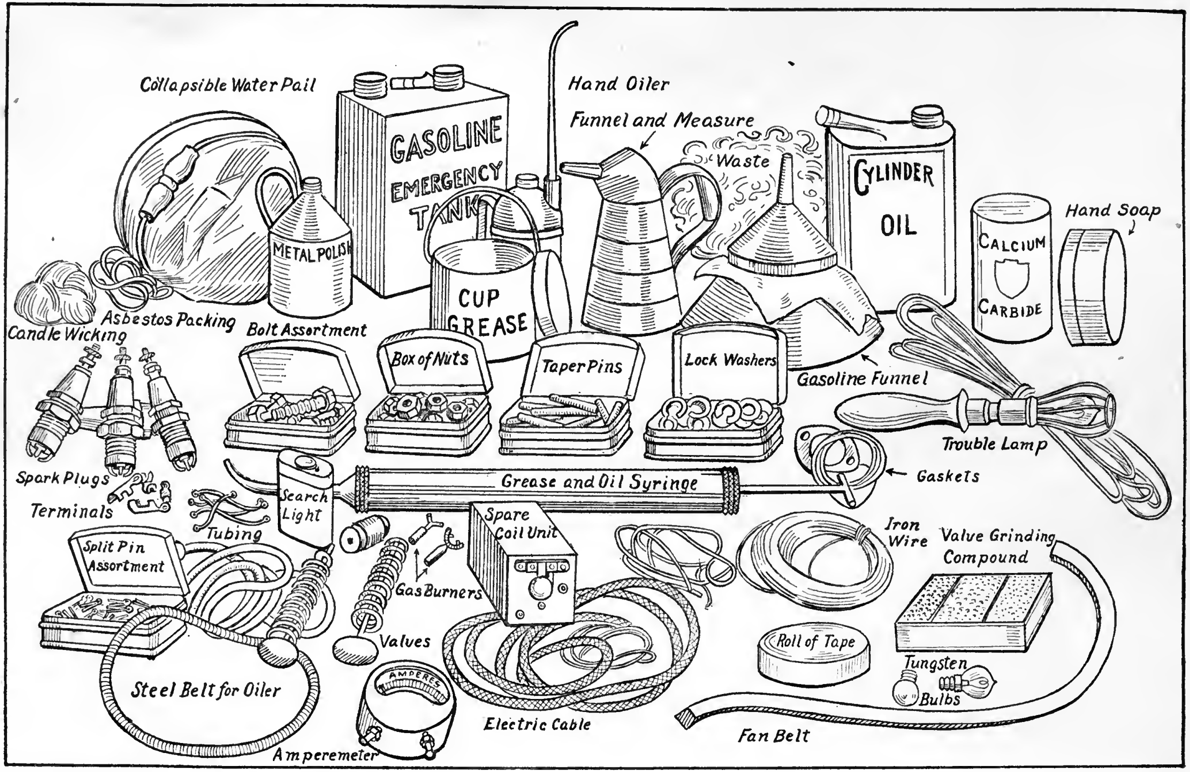


Fig. 361.—Group of Supplies That Will Be Found Useful When Touring or in Maintaining Motor Cars.

gasoline. That used for water should have a spout the full size of the filler opening in the radiator and it is desirable that it should include a wire gauze screen to filter the water of any particles of foreign matter that might clog the circulating system. The oil funnel should be small and it can be easily carried by nesting in one of the larger funnels. Sometimes a nest of three funnels may be obtained, one fitting in the other, and the entire set of three takes no more room than one funnel would ordinarily. The gasoline funnel should have a chamois skin through which all fuel would pass when filling the tank. This will remove the water and dirt always present in gasoline and is practical insurance against carburetion troubles.

A collapsible rubber water pail is useful on all types of cars, as it may be used to replenish the supply in the radiator from any wayside source when on the road or to carry water to the car for washing hands after repairs have been made. A small box of some good grease-dissolving hand soap, a clean towel and a piece of toilet soap take so little space that they can be stowed away anywhere, and their value is only apparent when a particularly dirty job of tire replacement or car repairing has been necessary on the road. A hand oil can and an oil syringe are needed to lubricate the various parts, the syringe being especially valuable to force oil at points that would not be easily reached with the hand oiler or that would require more lubricant than could be conveniently supplied by that method. A combination funnel and measure is often carried in place of an oil funnel.

It is well to carry a gallon can of cylinder oil and a small can of cup grease any time that one is touring away from home when there might be doubt of obtaining the same grade generally used on the car. With the ordinary single-chamber type of gasoline tank it will be found advantageous to carry a spare container holding two gallons of fuel. This occupies but little space and is practical insurance against being stalled by lack of fuel. Calcium carbide and a pair of extra gas burners should be carried if the car is lighted by acetylene gas from a generator, and extra Tungsten bulbs if the car is electrically lighted. A small hand search light is useful in looking at the gasoline level at night or in inspecting various points about the car where the presence of gasoline fumes would make the use of a naked flame dangerous. For more extended working after nightfall, a small portable trouble lamp, which will take its current from the ignition battery, will often demonstrate its worth.

The character of the spare parts needed will depend entirely upon the make of car, and any component must be chosen with reference to the weaknesses of the machine under consideration. The selection of the smaller parts for replacement should be by an experienced person who has had opportunity to study that make of car. It is well to have a spare valve complete with the spring retention collars and locking key on any make of car. At the present time practically all motor cars use valves that are interchangeable, and but one set for replacement is necessary. If, however, the valves are different sizes it is well to carry one each of the exhaust and intake. It is not necessary to carry these around on ordinary trips and they are merely provided as a safeguard when touring away from a base of supply. It is well to carry at all times assortments of small parts that are easily lost, such as split pins, lock washers, set screws, taper pins, cap screws, semifinished hex nuts, some copper and iron washers, and a few carriage bolts of the sizes used in securing the fenders to the irons or the running boards to the hangers. A roll of soft iron wire and a roll of electric tape are very useful in general repair work and rubber tubing may be included with advantage for repairs either to the gas piping, conveying acetylene gas to the lamps or the fuel line, leading from the gasoline tank to the carburetor.

Some of the supplies needed that need not be carried on the car are a box of valve-grinding compound, asbestos cord and candle wicking, several sheets of emery cloth and sand paper, and a supply of spare gaskets or packing material, if these are used on any portion of the power plant. If battery-and-coil ignition is used it is well to carry a spare set of batteries, extra primary and secondary wire, battery connectors and terminals, and either a complete coil unit or parts enough to make up a complete vibrator. If ignition is by a high-tension magneto, a complete set of the most important brushes and contact-breaker parts may be obtained at small cost from the manufacturer. No matter what kind of an ignition system is supplied it is well to carry a complete set of spark plugs. These members are liable to give considerable trouble and it is much better to replace a defective member with a new one rather than attempt to repair a poor spark plug on the road.

Spare oiler and fan belts are useful if either the mechanical oiler or cooling fan are driven in this manner. A complete set of tire tools and suitable equipment for tire repairing, such as considered in another chapter, should be provided. It is well to carry all smaller screws and parts in envelopes or small boxes which should be plainly marked so the contents could be ascertained at a glance without requiring examination. Any brightly finished steel part liable to rust should be covered with grease and wrapped in cloth or paper. All goods made of rubber should be wrapped up to protect them from oil, which has a harmful effect. Spark plugs may be carried in wooden or leather cases and they should be wrapped in such a way that they will not be jarred around, as this is liable to break the insulation or bend the sparking points.

One of the various forms of jacks shown at Fig. 362 should be included in the equipment. This member really forms part of the tire-repair outfit, though they are used on many occasions in making repairs when the tires are not at fault. The form at A is a simple lever-operated type having a double ratchet. A series of short strokes will raise the lifting ram, while slightly altering the magnitude of the stroke will allow the lifting ram to fall. In the jack shown at B the lifting ram is raised by means of gearing enclosed in the body of the jack. This is turned by means of a socket wrench, having a handle similar to a bit brace. In the form outlined at C the lifting ram has a screw thread cut on it and is raised by a bevel gear worked by a hand lever, which includes the ratchet mechanism. A very substantial form of direct lift jack is shown at D. The type outlined at E is used to raise the wheels from the ground quickly and easily and is intended for garage use. These are sold in sets of four and are used by many motorists to raise the wheels from the ground and relieve the tires of the car weight when the vehicle is not liable to be used for a few days or a longer period. The selection of a suitable jack is important, and while almost any form will be adequate to raise a light car the motorist should be sure that that used in connection with a heavy vehicle has ample capacity and that it is made of steel instead of treacherous iron castings, such as incorporated in the cheaper jacks.

Among some of the miscellaneous supplies that will be found useful may be mentioned rawhide lacing, fan belt connectors, leather

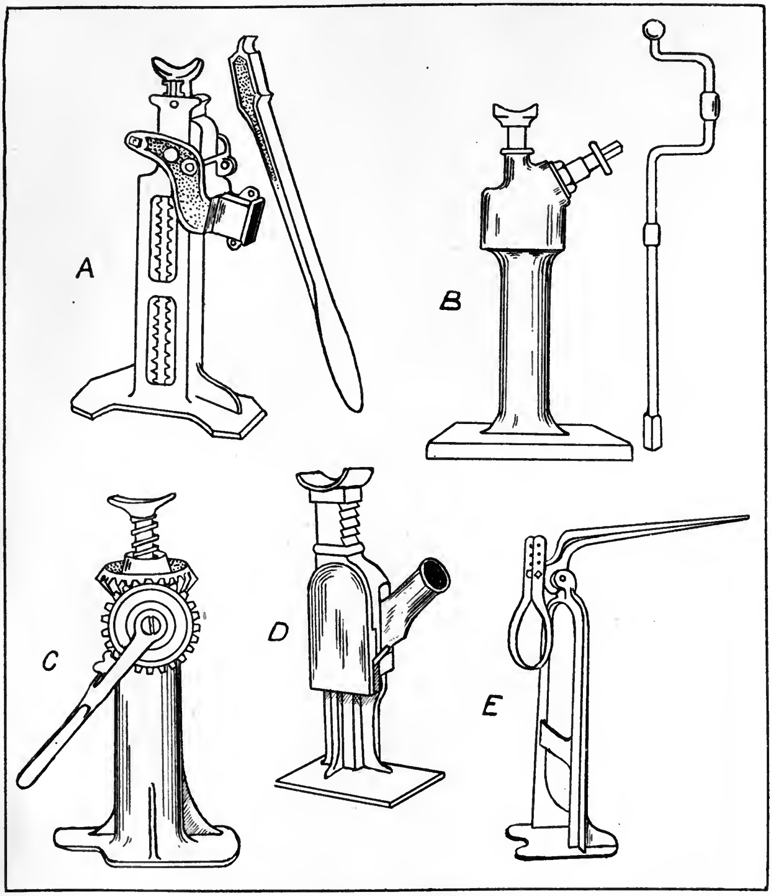


Fig. 362.—Leading Types of Car-Raising Jacks.

straps, dry powder fire extinguisher, hose clamps, brass polish and polishing cloths, covers of rubber or fabric for the lamps to protect them in wet weather and chain grips for the tires. If a cone clutch of the leather-faced type is used some clutch compound will be useful in event of harsh action or fuller's earth if the clutch slips. An emergency spring repairer, which comprises a steel forging and two clamps, enables one to make a broken spring operative and may be found of advantage if the car is operated over rough roads without shock absorbers. A coil of rope should be carried on any car that is to tour in comparatively unsettled countries, and special rope made especially for motorists' use may be obtained from the supply houses. These include thirty or forty feet of one half or three quarter inch diameter Manila rope, fitted with a heavy galvanized iron hook for attaching. The rope may be used for towing, in connection with a "Spanish Windlass" for pulling the car out of mud holes and ditches, for binding a rear wheel to get increased traction when that member drops in a mud hole, and for securing trunks and packages to the running boards or other portions of the car.

It should be noted that the equipment advised is more than ordinarily complete and it is not likely that any motorist will need more than the articles mentioned, and the majority will be able to get along very well with much less. Many of the supplies enumerated need not be carried on the car except when away from home, but it is well at all times to have a complete outfit of tools and tire repair appliances as well as necessary spare parts for eliminating tire troubles or engine derangement.

How Supplies May Be Carried.—A problem with many motorists is how a very complete outfit may be stowed on the average car. The views at Fig. 363 and Fig. 364 show how this difficulty has been solved on some of the leading automobiles of various types. At A the entire outfit necessary for tire restoration is carried at the back end of the car between the rear springs. The trunk case serves as an anchorage for two or three spare casings while the inner tubes and tire repair outfits, as well as many of the general supplies, are easily stowed away in the trunk. In the view of the rear end of the car shown at B a large tool box is placed back of the gasoline tank and has ample capacity to carry all tools and repair parts that would be needed for ordinary repairing. As the gasoline tank is carried back of the seat there is room under the front seat for many supplies. The form of trunk used in carrying clothing when on a tour is outlined at C. The trunk serves merely as a container and

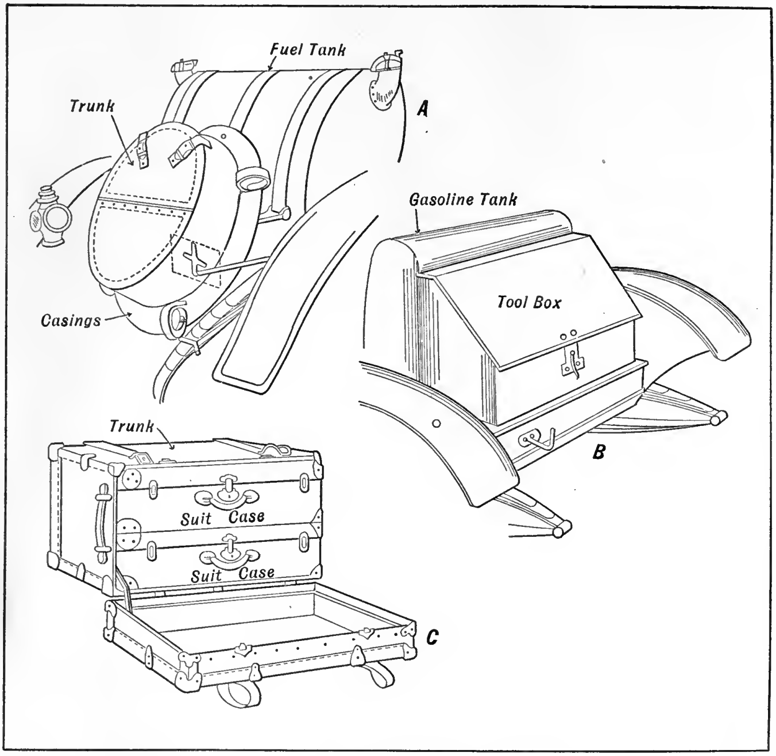


Fig. 363.—Some Conventional Methods of Storing Supplies and Equipment.

protector for the standard size suit cases that are employed to hold the clothing or supplies.

At Fig. 364, A, the very ingenious manner in which a prominent maker has utilized the space back of the seat of the torpedo roadster for stowing suit cases is shown. To gain access to these the front seats are pushed forward, the center partition between the seats is raised, and the seat back is allowed to fall. The result is that a large opening is provided through which the suit cases or other bulky supplies may be easily placed in the body compartments. In this the spare tires are carried at the rear end of the car while the tools that are apt to be often used are stowed away in an easily reached chest on the running board of the car.

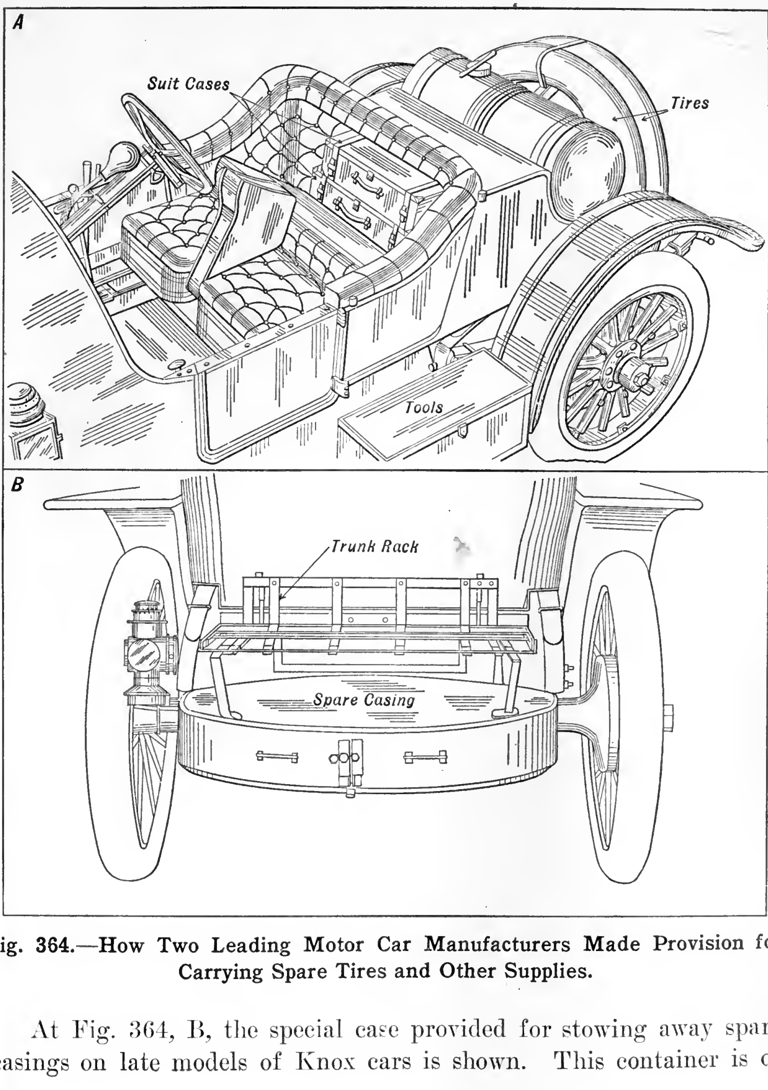


Fig. 364.—How Two Leading Motor Car Manufacturers Made Provision for Carrying Spare Tires and Other Supplies.

At Fig. 364, B, the special case provided for stowing away spare casings on late models of Knox cars is shown. This container is of metal and access to its interior is obtained by releasing the catch and sliding the two semicircular doors around to the back end. This view also shows the form of trunk rack provided on many touring cars to take the automobile trunk shown at Fig. 363, C. Two views which show the practical disposition of the various accessories on conventional touring cars are shown at Fig. 365. A side elevation

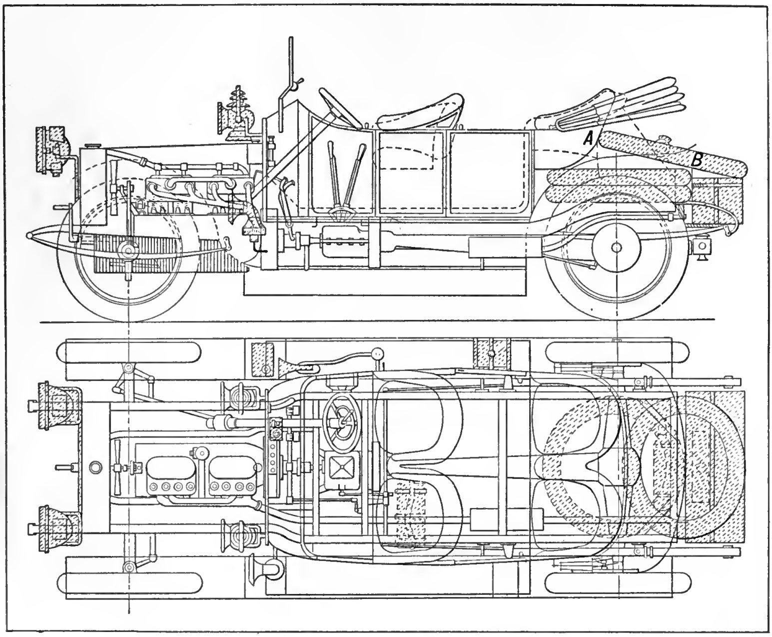


Fig. 365.—Side Elevation and Plan View of Modern Motor Car Showing Disposition of Various Articles of Equipment without Hampering Passengers or Reducing Carrying Capacity.

and a plan view of the vehicle is given, and the location of the essential accessories and supplies are so clearly shown that it would seem unnecessary to describe these in detail. The placing of the lamps, warning signal, wind shield, top, spare casings, and various cases for stowing away the smaller parts may be readily ascertained by a study of the illustrations.

CHAPTER XII

Operating Advice and Explanation of Automobile-Control Methods—Utility of Spark and Throttle Levers—Obtaining Various Speed Ratios with Friction Transmission—How Planetary Gearsets are Controlled—Shifting Sliding Gears by Progressive and Selective Systems—Standard Automobile-Control Systems Described in Detail—Maintenance Hints of Value—Suggestions for Oiling—Winter Care of Automobiles.

The basic principles of gasoline-motor-car operation are practically the same in all types of cars, though the various forms of speed-changing mechanism demand distinctive methods of control in each specific case. It is not possible to give definite information that will apply to controlling all types of cars, but the general advice given can be applied to all cars, especially the instructions relating to the method of motor-speed control. The methods of regulating the motor speed will be the first point considered; then the control system when the simpler forms of transmission are used, and finally the method of obtaining various speed ratios with sliding gearsets.

How the Motor Should Be Started.—One of the most important points in the education of the novice motorist is the best method of starting the motor if a self-starting device is not provided. Before the engine is set in motion certain precautions must be observed regardless of the make or type of car. The gasoline tank, radiator, and lubricating-oil container should be inspected to make sure there is enough fuel, water, and lubricating oil. The shut-off valve in the pipe line leading from the gasoline tank to the carburetor is opened so the fuel will flow to the vaporizer. The carburetor should be primed by means of a small plunger usually carried in the float-bowl cover, and if a small resistance is felt to the downward movement of the primer or if gasoline escapes from the bottom of the mixing device, this may be considered a positive indication the fuel from the tank has reached the carburetor and that gasoline is present at the spray orifice. The next step is to see that the change-speed lever is in a neutral position or that the clutch pedal is disengaged. The spark-control lever, which is usually carried on the steering wheel, should be set at the full retard point. In some cars this may be at the back of the sector, while the retard position may be the other extreme in other motor cars.

If one attempts to set an engine in motion by means of a hand crank with the spark lever advanced so that an early spark is obtained, the motor may "kick back," and this reversal of motion, which is due to premature combustion, may sprain the wrist or break an arm. It will be well to open the throttle or gas lever a little to insure that a charge of combustible gas will be inspired into the motor. The engine should be turned over several times as briskly as possible, and then the switch which completes the electrical circuit between the battery and the ignition mechanism should be put into circuit and the switch plug inserted. The hand crank is pushed in until it engages a ratchet member on the front end of the crank shaft, and then the motor should be turned by pulling up on the starting handle with the left hand.

The hand crank should always be engaged so that an upward pull will be necessary to turn the crank shaft, and a point that cannot be too firmly impressed upon the embryo motorist's mind is that gasoline engines should always be started by pulling up on the handle of the starting crank, never by pushing down. If the starting handle has been properly placed and the engine has been turned over enough without the switch so the cylinders hold a gas charge, and the switch circuit is closed when a decided resistance is felt as the crank is turned, indicating that the piston in the cylinder in which the gas charge is about to explode is nearing the compression point, a single, quick, strong pull on the crank should be sufficient to start any properly adjusted motor.

Multiple-cylinder engines, especially those of the four- and six-cylinder type, are started much more easily than the one- and two-cylinder forms. These can often be started by turning the starting handle over briskly so the motor will take in gas but without the switch closing the electric circuit. To start the motor the switch is closed and a spark will be produced in the cylinder about to fire (only in cars equipped with battery ignition) by moving the spark lever from one end of the sector to the other. As soon as the engine becomes started it should be kept from racing by shutting down the supply of gas to the point where the motor will turn freely and yet slowly.

Most hydrocarbon vehicle motors have a certain degree of flexibility, i. e., they may be run slow or fast, and the speed may be accelerated or cut down as desired within a range from 200 revolutions per minute to the maximum, which will vary with the type of motor.

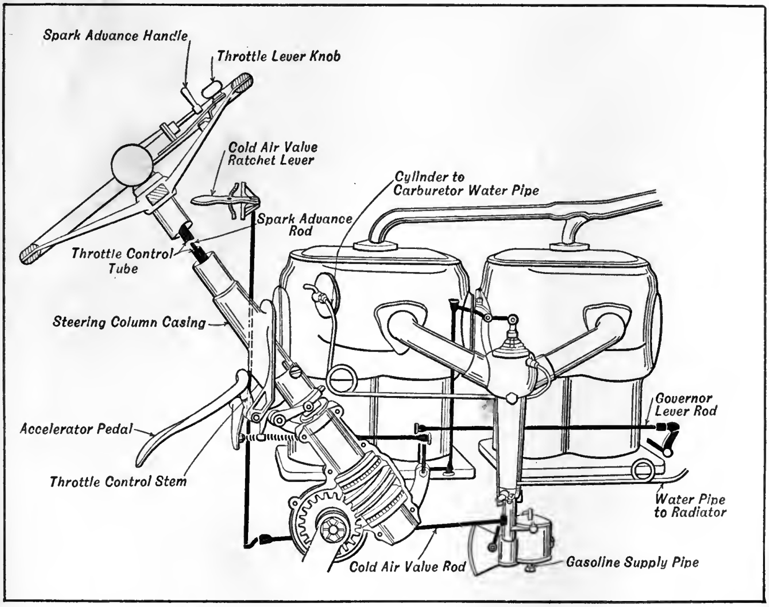


Fig. 366.—Parts of Motor Control System of Peerless Car. Spark Advance Regulated by Small Hand Lever. Gas Supply Controlled by Automatic Engine Governor, Accelerator Pedal or Throttle Lever on Steering Wheel.

This is an important advantage, inasmuch as it permits one to regulate the vehicle speed on most occasions by a touch of the throttle alone. The engine speed of practically all automobiles is controlled by two ways, though usually these are employed in conjunction. One of these consists of varying the time of the spark in the cylinder, the other regulating the amount of gas supplied.

A typical carburetor-control system is shown in detail at Fig. 366.

The throttle, in this case, may be controlled by three distinct means. One of these is a centrifugal governor which shuts off the gas supply automatically if motor speeds exceed a certain predetermined point. The governor may be temporarily dispensed with by pressing down on the accelerator pedal, which will open the throttle directly, or by means of the throttle lever carried on top of the steering column. The usual method of driving is to set the throttle lever at a point which will give the minimum speed desired and depend upon the governor to take care of other speed fluctuations. If it is necessary to get more gas than the governor will allow to pass, the accelerator pedal can be used to operate the throttle directly. The function of the spark lever is to regulate the time of sparking to the point best suited to the needs of the engine.

The question of motor-speed regulations seems to be a simple one, but many motorists learn proper methods of spark- and throttle-lever placing only after considerable driving experience has been obtained. Motor-speed regulation depends upon two factors. First, advancing the time of sparking to the most efficient point after the engine has once been started, and secondly, increasing the amount of mixture supplied the cylinders. The spark and throttle levers, while designed to be manipulated independent of each other, usually move with a certain definite relation. It would not be good practice to run an engine with the spark lever way advanced and gas-supply throttle nearly closed; nor would good results be obtained if the spark lever was retarded and the throttle opened as it is desired to increase the motor speed. It is not difficult to understand the function of the throttle lever and how the admission of more gas to the cylinders would act in creating more power, just as augmenting the steam supply to a steam engine will increase its capacity.

The rules for manipulation of the spark lever are not so well understood. In order to make clear the reason for intelligent manipulation of the spark handle there are certain points that must be considered. On most automobiles there is a position of the spark lever, usually at the center or intermediate point of the sector over which it moves which corresponds to the normal firing point. If the spark lever is not advanced beyond this position, and the motor is turning over slowly, the gas in the cylinders is being exploded when the pistons reach the end of their compression stroke. When the gas is fully compacted the explosion or power obtained from combustion is more powerful than if the spark fired gas which was not compressed properly. The electric spark is not produced at the exact time that the motor should be fired at all speeds, and if the spark was supplied the very instant of full compression irrespective of the speed of rotation, there would be no need of moving the spark lever.

Not only is the current apt to lag, but it takes a certain definite amount of time to set fire to the gas. It requires the same amount of time to ignite the gas, of given composition, regardless of the speed of the motor. If the motor is only turning at a few hundred revolutions per minute there is ample time to ignite all gas charges positively, but if the motor speed increases and the explosions occur oftener, then one must compensate for the more rapidly occurring combustion periods by arranging to start igniting the gas earlier so the explosion will occur when the piston is at its highest point in the cylinder. The compensation for lag is made by advancing the spark. The spark lever on the steering wheel or column moves a commutator, if battery system is employed, or the magneto-contact-breaker box, if that form of current producer furnishes the ignition energy. The amount of spark advance needed depends on engine speed and the greater the piston velocity the more the spark should be advanced.

It is possible to advance the spark lever too far, and when this occurs the gas is exploded before the piston reaches the top of its stroke and premature explosion takes place. As a result of this the upwardly moving piston is forced to overcome the resistance exerted by the expanding gas of the ignited charge in completing the remainder of the compression stroke, and before it will return on the power stroke. The injurious back pressure on the piston reduces the capacity of the motor and a pounding noise similar to that produced by loose motor parts gives positive indication of premature ignition due to excessive spark advance.

At the other hand, if the spark lever is not set as far forward as it should be, the explosion may be late because of the "retarded spark." If the spark occurs late in the cycle, the charge is not fired until the piston has reached its highest point and after it has completed a small portion of its downward movement. As the point of maximum compression is passed and the piston moves down in the cylinder, the size of the combustion chamber augments and the gas begins to expand again before it ignites. Owing to the moderate compression the power resulting from explosions is less than would be the case with a higher degree of compression. To secure power it is necessary to supply more gas to the cylinders. Driving with a retarded spark produces heating of the motor and is wasteful of fuel.

For ordinary running the spark lever is usually placed about midway of its travel on the sector, and as a general rule an engine with magneto ignition does not require the frequent manipulation of the spark necessary when current is produced by chemical means. As the engine speed increases the current produced by the magneto is proportionately augmented, and the spark lever need not be advanced from the center position except under conditions which permit of exceedingly high engine speeds.

The diagram presented at Fig. 367 is furnished by the Cadillac Motor Car Company to owners of its cars, and shows the position of the spark and throttle levers to obtain various engine speeds when the car is on the direct drive. At five miles per hour the throttle is practically closed and the spark lever has been advanced about a quarter of the way down the segment. To obtain a speed of eight miles per hour the spark lever is moved to the point on the steering-wheel sector indicated by the letter C. The throttle lever is not disturbed. Moving the spark lever about two thirds of the way on the sector will increase the speed of the car to nine miles per hour. From this point speed ratios are augmented by moving the throttle lever and the car speed increases progressively as the amount of gas supplied the engine is augmented. For higher speeds than twenty-five miles per hour the spark and throttle levers are moved toward the end of the sector and it is usual practice to advance both in conjunction beyond this point.

Summing up, it will be patent that the greatest economy of fuel will result when the car is driven with as little throttle opening as possible, and with the greatest spark advance the motor speed will allow. To obtain maximum power, as in hill climbing on the direct drive, the spark lever should never be advanced beyond center and the throttle should be opened as wide as possible. For extreme high

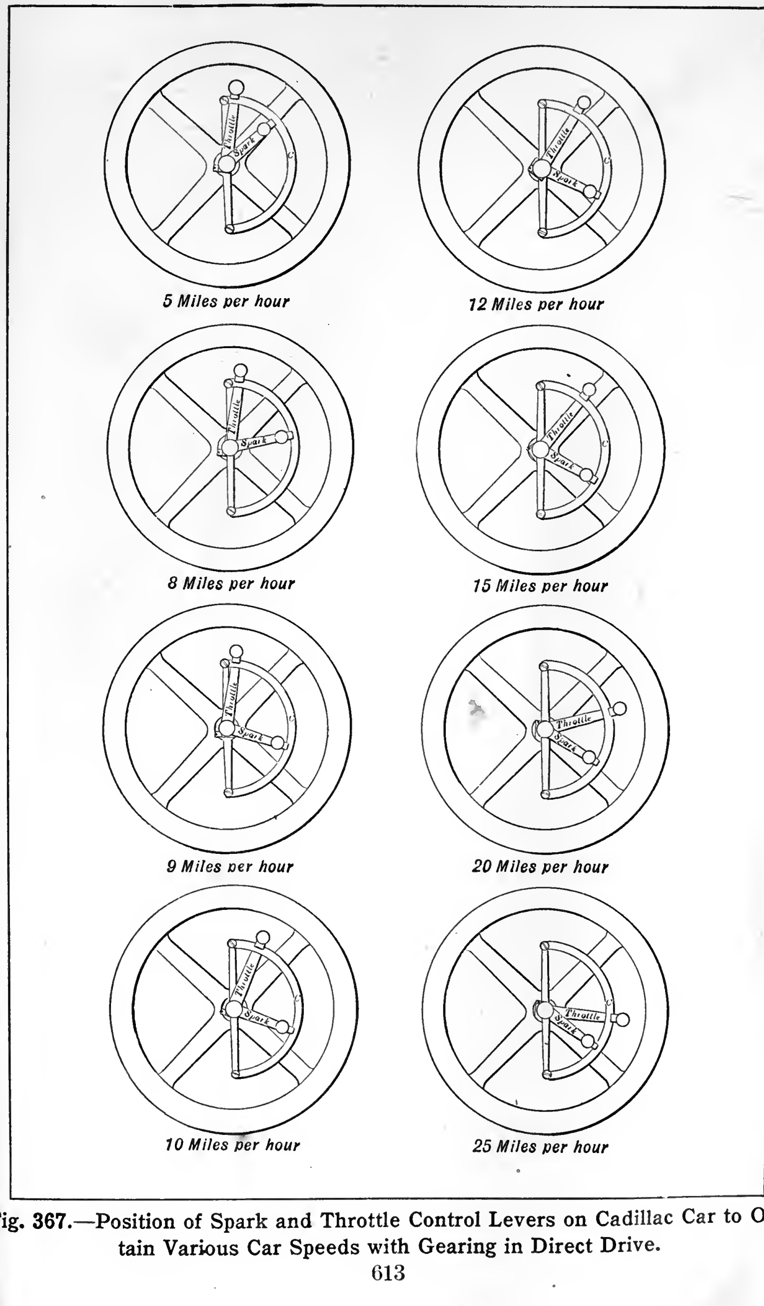


Fig. 367.—Position of Spark and Throttle Control Levers on Cadillac Car to Obtain Various Car Speeds with Gearing in Direct Drive.

speeds, the throttle should be advanced to a point about midway of its travel before the spark lever is advanced beyond that point. If this does not give the required increase in speed, the spark lever should be advanced as far as possible and the amount of gas increased, by moving the throttle lever from its central position to the extreme position on the sector. Control-lever placing varies on nearly all cars, but the most common position is on top of the steering column, where they are convenient to operate and very accessible. In some cars the spark and throttle levers may be placed under the steering wheel and on one side of the steering post, one being located above the other. In other vehicles, they are disposed under the wheel and on opposite sides of the steering post. Some designers do not furnish variable spark when a magneto is provided. The magneto contact breaker is advanced to the point where the best operation under average conditions is attained, and motor-speed regulation is entirely by using the throttle lever or accelerator.

Controlling Cars with Friction Transmission.—After the engine has been started the next point is to put the automobile in motion. The means for obtaining the various speed ratios will determine the steps that should follow. When a friction or planetary transmission is installed the control is very simple and usually a single lever suffices to furnish all desired speed ratios. The Carter Car control system is shown at Fig. 368 and is a good example of the simple method of control possible when friction-disk change-speed gearing is utilized. One hand lever at the side of the car serves to move the driven member to its various positions on the face of the driving member. The inner foot pedal is employed to bring the friction disks together and establish driving contact between them when the proper speed position has been selected with the hand lever. The other pedal is used to apply a running brake at the rear wheels. Motor speed is regulated by spark and throttle levers on the steering wheel.

With this form of control the friction pedal is released before the engine is started and as this breaks the driving connection between the friction disks, the engine can be turned without moving the vehicle. After the motor is started in the manner previously indicated, the speed-changing lever is placed at a position about midway in its travel or so it will line up with the bulb of the horn shown in illustration.

This gives one of the lowest speed ratios. To start the car the friction pedal is pressed with the left foot until sufficient pressure exists to cause the driving member to turn the driven wheels and transmit the engine power to the rear wheels. After a certain degree of headway

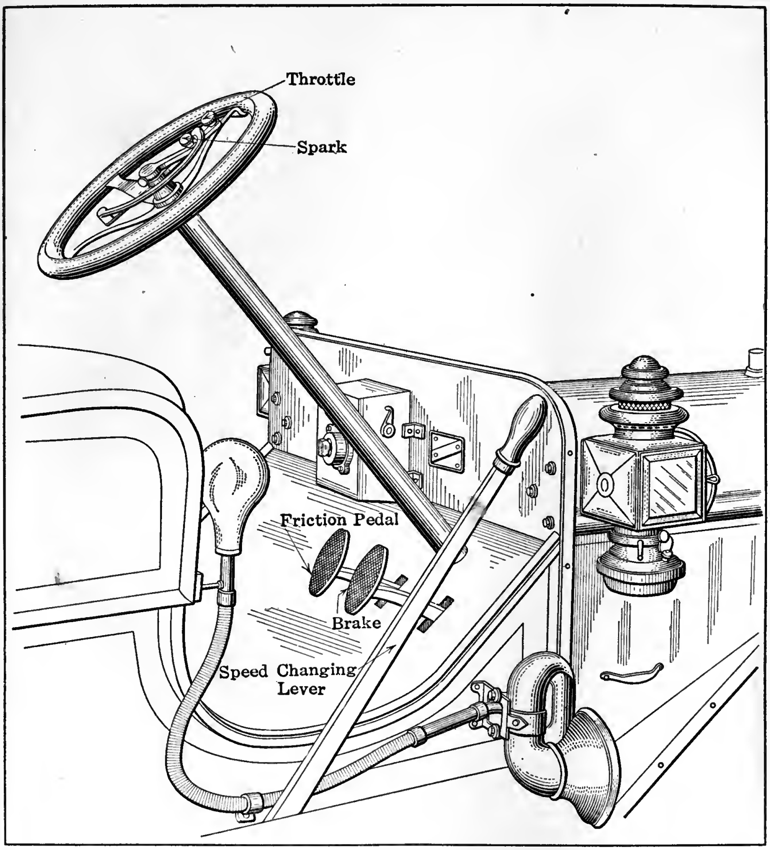


Fig. 368.—Control System of Carter Car, Which Employs Friction Transmission.

has been attained, the friction pedal is allowed to return to its free position and the hand lever is pushed forward a few inches to give a slightly higher speed. The friction pedal is again depressed and when sufficient pressure is exerted the car will move forward at a higher speed. The farther forward the handle is placed, the higher the vehicle speeds, and if the handle is brought back beyond a central position a reverse motion is obtained.

The friction pedal may be locked at any desired point by tilting the foot pad up by raising the heel. When it is desired to stop the car the friction pedal is released by bearing down on the lower portion of the foot pad, which loosens the ratchet lock and by pushing on the brake pedal. It is important that the friction pedal be applied gradually and that it is not pressed down any farther than is necessary to drive the car. The amount of pressure will depend on the road conditions, and the lighter the degree of pressure the less wear will take place on the friction-wheel fiber ring. When on a hill, or in sand, the friction pedal will have to be pushed up harder than when the car is driven on a level highway with a good surface.

Before the hand lever is changed from one position to another the friction pedals should always be released. An emergency braking effect may be obtained by pushing the hand lever in reverse position and applying the friction pedal if the car is going forward, or vice versa, if the car is traveling in a reverse direction. One of the advantages of the friction transmission is that it is difficult to injure it by careless handling because there are no gears to be stripped if these are not meshed properly. The transmission is practically noiseless and speed changes are effected easily and noiselessly.

Planetary Gears Easily Controlled.—One of the advantages of the planetary gearset, when applied in the two-speed forward and reverse forms is that the method of obtaining the various speed ratios is very simple and easily understood. At Fig. 369 the control system of some of the lighter Maxwell cars is shown and the various positions of the lever to obtain the different speeds are clearly indicated. On these cars, the speed of rotation of the double-cylinder motor is regulated by a small pedal connected to the throttle of the carburetor and a spark lever at the top of the steering column, under the steering wheel. The speed changes are obtained by a single hand lever and the hub brakes are applied by the usual form of pedal.

Five positions of the handle give two neutral points, one reverse motion, and two forward speeds. Ordinarily the lever is in an approximately vertical position and is at the neutral point between the reverse and slow speed. When pulled back from this position a re-

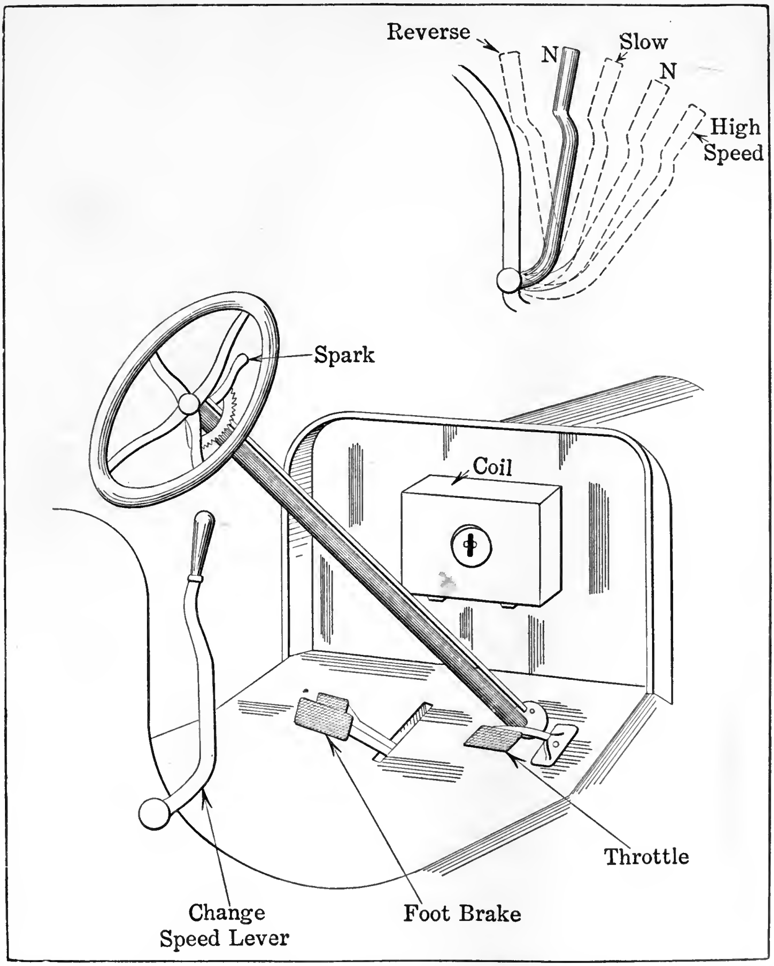


Fig. 369.—Simple Speed-Regulation Method on Maxwell Cars Furnished with Planetary Gearsets.

verse motion is obtained. If pushed forward the slow-speed gears are put into action. Moving the hand lever from the slow-speed position forward gives the second neutral point, while the high speed or direct drive is obtained by pushing the lever to the extreme forward position. The lever must be held in the reverse position but can be locked into low and high speeds.

When running the car under conditions where it is not necessary to go into the reverse the lever may be pulled from the high-speed position to the neutral point between high and slow speeds. If the car is stopped it can be easily started forward again by pulling the handle back into slow speed from neutral position and then forward to engage the direct drive. If the handle is pulled way back out of high speed into neutral position between slow and reverse, either of these ratios may be easily obtained. A point necessary to consider when operating a planetary transmission is that the slow and reverse speed must be applied gradually and that the engine be speeded up pretty well before either reverse or slow-speed bands are tightened. After the car has attained a certain degree of momentum on the low speed the lever should be put forward into the high-speed position gradually in order to avoid the sudden jump which always obtains when changing from the low to the high speed of a two-speed car. This jump is caused by a sudden acceleration due to the higher gearing, provided by the direct-drive position which is much higher than the maximum speed permitted by the slow-speed gears.

The Ford car is one of the most popular of moderate-priced automobiles and over 100,000 of the Model "T" are now on the road. The control system of this car is extremely simple and yet it is different from that of any other automobile. The gearset, which has been previously described, is a planetary type which gives two forward speeds and a reverse motion. The conventional form of steering wheel is used to control the direction of car travel, and spark and throttle levers are mounted on the steering column beneath the wheel to control the speed of the power plant. It is in the method of obtaining the various speed ratios that the control system is distinctive. As will be seen by referring to Fig. 369, A, three pedals and a hand lever are provided on the left side of the car. The pedal on the extreme left is used to control the high- and low-speed clutches and is marked "C." That next to it, which is marked "R," is used to constrict the reverse band of the transmission and obtain reverse motion. The pedal at the right, which is provided with a letter "B" cast on its surface, is used to apply the foot brake.

The hand lever engages the high-speed or direct-drive clutch when thrown forward and when pulled back it actuates the emergency

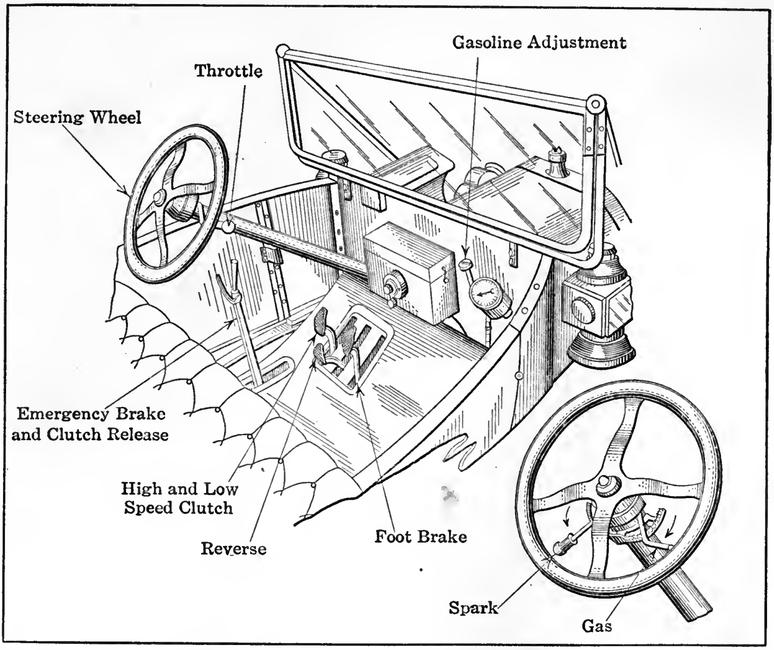


Fig. 369 A.—Outlining the Distinctive Control System of Ford Model "T" Automobile, Which Employs Two-Speed and Reverse Planetary Gearing. Location of Spark and Throttle Levers Clearly Shown in Inset.

brake. An interlocking connection is provided so the emergency brake cannot be applied without releasing the direct-drive clutch. The lever may be set in a neutral position and the clutch will be released without applying the brake when it is approximately vertical. When the high speed is in and the hand lever is thrown way forward the high-speed clutch may be released by a light pressure on pedal "C" and a further movement of this pedal will apply the low speed. Thus one pedal gives control of both high and low speeds forward and the clutch can be released in exactly the same manner as that of a sliding-gear car when it is desired to slow up, such as for turning a corner, descending a hill or passing another vehicle.

Before starting the car the hand lever must be in a vertical position, this releasing the clutch and applying the emergency brakes. To start the car, after the engine has been started in the usual manner, the foot is placed on the clutch pedal to keep it in a neutral position, while the hand lever is thrown as far forward as it will go. The engine is then accelerated and the clutch pedal is pushed forward until the slow-speed band tightens around the drum of the transmission and the car gathers headway on the lower ratio. After it has attained a certain momentum, the clutch pedal is allowed to drop back gradually into the high-speed position. The foot may then be removed until such times that the clutch must be disconnected. Before applying the foot brake, which is done by pressing with the right foot upon the pedal marked "B," the clutch pedal should be put in neutral position with the left foot.

To reverse the car, it must first be brought to a standstill. The engine is kept running and the clutch is disengaged with the hand lever, which is placed in the neutral position but not pulled far enough back to apply the emergency brake. The reverse pedal marked "R" is then pushed forward with the left foot, leaving the right one free to use on the brake pedal if needed. To stop the car, the throttle is closed so that the engine will not race; the high speed is released by pressing the clutch pedal forward into its neutral position and applying the foot brake slowly, but firmly, until the forward motion of the car is arrested. It is imperative that the foot be retained on the clutch pedal until the hand lever is pulled back to its neutral position. The placing of the spark and throttle levers is clearly shown in the inset in the right-hand corner of the cut, both levers being pulled back to accelerate the motor and pushed forward to slow it down. The same rules previously given for the manipulation of the spark and throttle levers apply just as well to this make of car.

In the Liberty-Brush runabout the control system is somewhat similar to that previously described, except that the hand lever at the side of the car is operated selectively rather than progressively. The control system is shown at Fig. 370, and in the upper corner of the illustration the different positions of the lever in the gate are shown to obtain the various speeds desired. Engine speed is controlled by spark and throttle levers under the steering wheel in the usual manner.

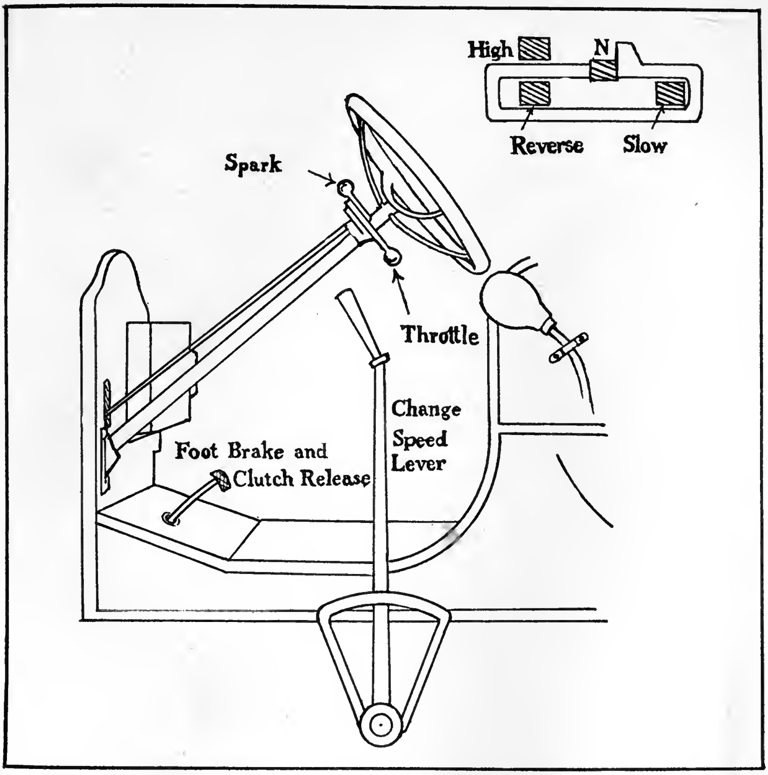


Fig. 370.—Selective Change-Speed System of Liberty-Brush Light Runabout.

The lever works in a gate arrangement and normally is in the position indicated by the letter N in the inset. In this neutral position the hand lever is normally straight up and down.

To obtain slow speed the top of the handle is pushed out and the lever moved sideways until it is in the outer slot. The lever is then pulled back until a distinct resistance is felt, at which time the slow-speed band will be clamped around the slow-speed drum of the transmission and the gearing contained therein be in action. If the lever is pushed from the slow-speed position forward until another resisting

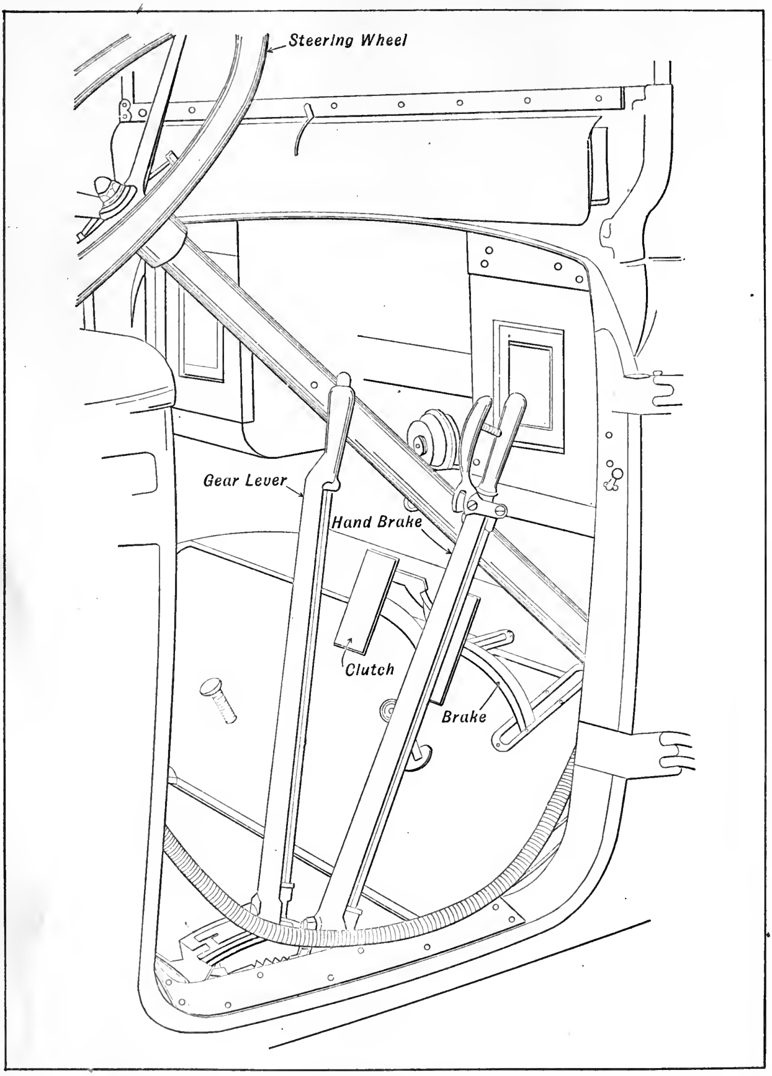


Fig. 371.—Side-Control Levers and Pedals of Pierce-Arrow Sliding-Gear Cars.

influence is felt, the gearing will be in reverse ratio. To engage the direct drive, the hand lever is pulled through the neutral slot and pushed forward in the inner slot. The single-foot pedal not only acts to apply the foot brake, but will automatically disengage the high-speed clutch before the brakes are applied without touching the hand lever. In driving the car on the high speed, if it is desired to slow up to pass another vehicle or turn a corner, a slight pressure on the pedal will release the high speed. A greater degree of pressure on the pedal will apply the foot brakes.

Operating Sliding Gearsets.—Two sliding gear systems are fitted to motor cars, but at the present time the progressive system of control has been almost entirely superseded by the selective system. The principles of operation are practically the same as relate to clutch operation and gear engagement, but in the progressive system it is necessary to move the gear-shift lever from one end of a segment to the other to obtain the range of speed. In the selective system a gate segment is utilized and the hand lever is moved only short distances to select the speed required.

The control system of a typical selective sliding-gear car is shown at Fig. 371. Engine-speed regulation is by spark and throttle levers at the left side of the steering wheel operated in the usual manner. Two pedals are provided and two hand levers. The pedal that is to be worked by the left foot is used to release the clutch, while that that is applied by the right foot actuates the running brake. The outer hand lever works on a notched segment and is pulled toward the operator to apply the emergency brake. The inner lever works in a gated segment and is employed to obtain the varying speed ratios. Another complete control system in which side levers are employed with all parts clearly depicted is shown at Fig. 372. These may be considered representative of conventional practice and the majority of the sliding-gear cars are controlled in practically the same manner.

How Selective Gearsets are Operated.—The arrangement of guiding gates which are used with selective systems of gearset control are shown at Fig. 373. In all of these the neutral point is usually at the center of the bars dividing the segment into slots and the lever can be easily moved in either direction to engage the speed desired. On the Peerless cars, which are provided with a four-forward speed and reverse gearset, there are three positions or slots for the speed-changing lever at the front end of the segment and two at the rear. To engage the reverse gear the lever would be placed in the slot indicated by the letter "R." To give the lowest forward speed the lever would be pulled out of the reverse slot and pushed forward into the adjacent one, indicated by number one; pulling the hand lever back out of this slot, into that marked number two will give the second speed. To engage the third speed the shift lever would be pulled out

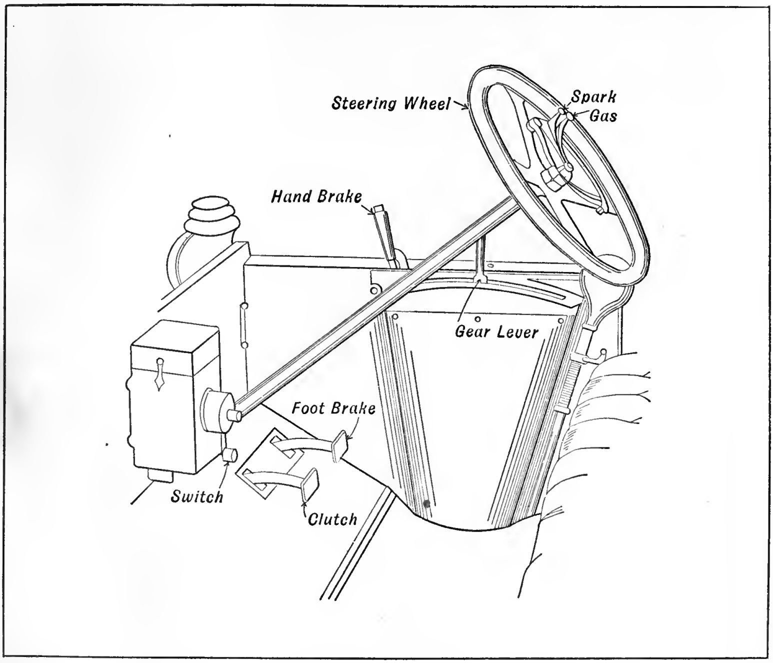


Fig. 372.—Complete Control System of Buick Automobiles Showing Engine-Regulating Levers on Steering Wheel, Enclosed Hand Levers and Foot Control of Clutch and Running Brake.

of the center slot and into the outside one and pushed forward until it filled the slot marked three. For the highest speed, the hand lever would be pulled from slot three to the outside rear slot four.

On the Locomobile cars a four-speed transmission is provided, but the arrangement of the control slot differs somewhat from that used on the Peerless cars. As shown in the cut, the lever is in neutral position and can be moved sideways into either the inner or outer slot. To obtain the reverse speed the handle is pushed as far forward

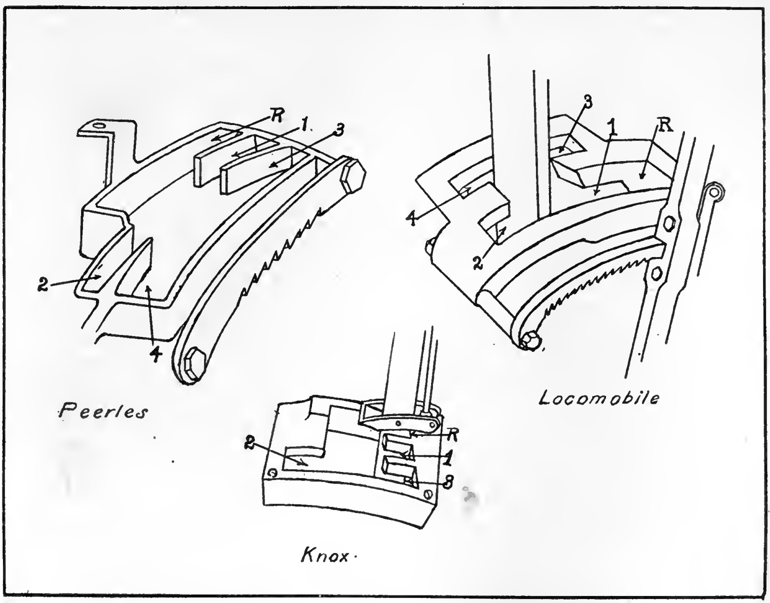


Fig. 373.—Change-Speed Gates for Three- and Four-Speed Selective Transmissions.

in the outer slot as it will go. Pulled back from this position but keeping it still in the outer slot will give the first speed. Pulling the lever back from point indicated by one to slot two will engage the second speed. The higher ratios are obtained in the inner slot. A forward movement of the lever engaging the third speed, while a pull back will engage the highest ratio.

On Knox cars, where three forward speeds are provided, the guiding gate is arranged in such a manner that the reverse, first, and third speeds are obtained by pushing the lever into one of three slots at the front end of the gate, while the second-speed gears are meshed by pulling the hand lever back into the one rear slot.

In operating a car with the selective method of control it is necessary that the gear-shift lever be in a neutral point if the clutch is engaged before starting the engine. After the motor has been started and is running at the proper speed, and it is desired to start the car, the first step is to release the emergency-brake lever and depress the

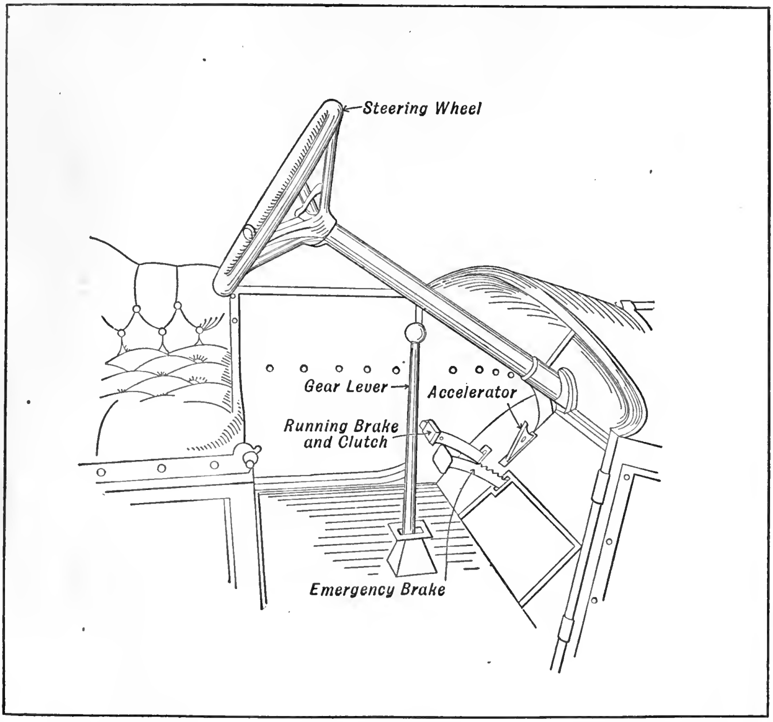


Fig. 374.—Reo Control System with Single Centrally Located Gear-Shift Lever and Steering Wheel on Left Side.

clutch pedal so that the driving connection between the engine and gearset is interrupted. With the clutch pedal depressed fully the hand lever is pushed into the slot which will give the slowest speed; then the clutch is allowed to engage slowly and the start forward is made on the lowest speed. After a certain degree of momentum has been attained the clutch pedal is again depressed and the speed lever shifted into the next higher speed ratio. The velocity of the car is thus gradually increased by moving the lever in steps from the lowest to the highest ratio. With any form of sliding-gear transmission it is imperative that the clutch be released every time a change of speed is to be made and the clutch should not be engaged again until the gearing is positively in mesh.

When one desires to stop the car the first step is to release the clutch by pushing forward on the clutch pedal with the left foot and apply the foot brakes with the right foot. The gear-shift lever is brought into a neutral point and then the clutch may be engaged again, if desired. On many cars the emergency-brake lever and clutch-shifting mechanism are interlocked in such a manner that the clutch is released automatically when the hand-brake lever is applied. The emergency brakes of the average car are seldom used in normal operation, the main reliance of most drivers being foot-operated service brakes. When it is desired to lock the car the emergency-brake lever is pulled back until the brakes are engaged and is retained in that position by a locking ratchet that engages suitable teeth cut into the brake-lever segment.

There is some difference of opinion regarding the placing of the steering wheel and whether it should be on the right or left side of the car. Most American motor cars, which originally were copies of foreign productions, place the wheel and control levers at the right side of the car, because they were disposed in this manner on the European cars from which the first American vehicles were copied. The road rules in Europe are different than in this country in that a driver has to pass a vehicle going in the same direction on the right and must keep to the left of the road. This made the right hand placing of the wheel logical and desirable. In this country, however, the rules of the road are that all vehicles must keep to the right and when one passes another conveyance going in the same direction it should be passed on its left side. This makes the right-hand control, which is logical and desirable in Europe, unsuitable for road laws of this country.

To be logical the steering wheel of American cars should be placed at the left side instead of the right. A number of designers follow this rule, but in order to conform as much as possible with American practice the gear-shift lever is placed in the center of the car where it can be operated by the right hand instead of at the left side. A typical left-hand control system is shown at Fig. 374. In this a single-hand lever is mounted in the center of the floor board and is moved in four directions. It may be rocked to the right or left and pulled back or pushed forward in either of these positions. When the

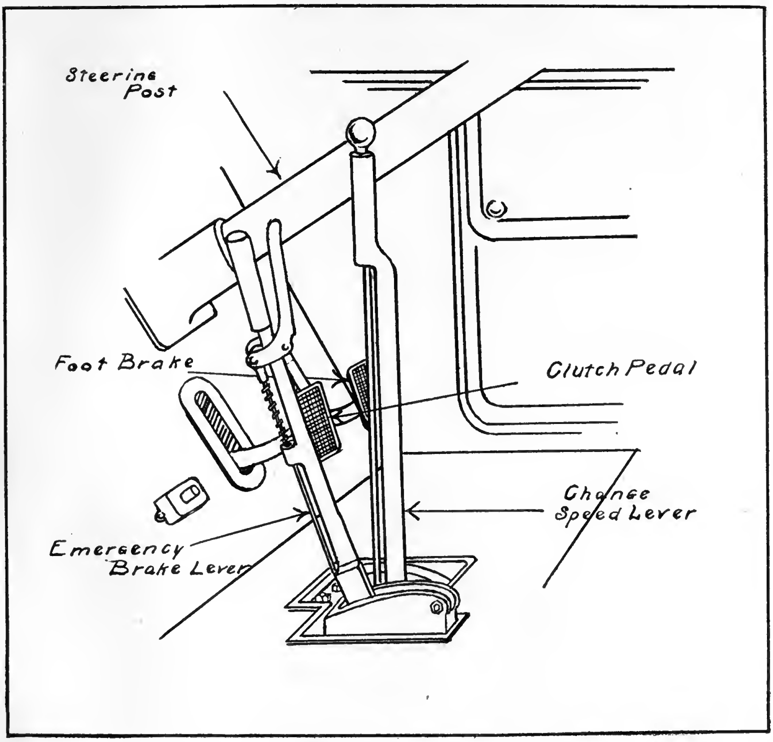


Fig. 375.—Speed-Change Levers of Knox Cars.

lever is straight up and down it is at the neutral point, the three forward speeds and reverse motion are obtained by rocking the lever from side to side and pushing it forward or backward as conditions demand. Two pedals are provided. That at the extreme left serves to release the clutch and apply the service brake, while the one operated by the right foot actuates the emergency brakes. When a single pedal is used for service-brake application and clutch release, it is

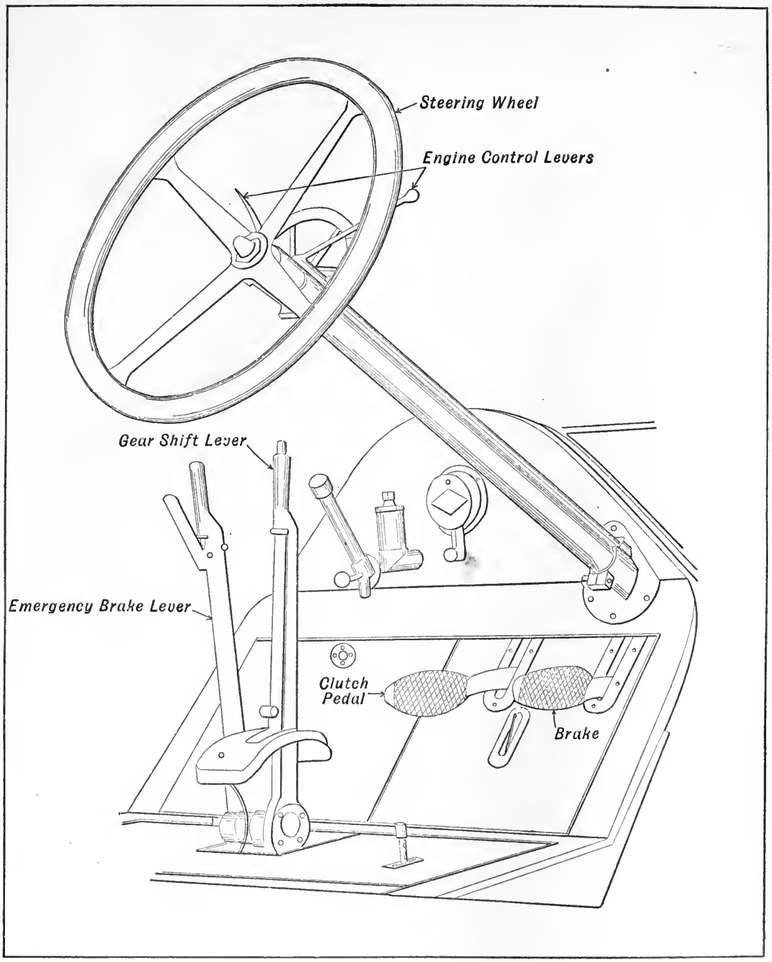


Fig. 376.—Complete Control Group of Mitchell Motor Cars.

depressed about half its travel to disengage the clutch and applies the running brake from that point to the end of its radius of movement.

Many designers who favor the right hand placing of the steering post locate the gear shift and emergency-brake levers in the center of the floor in order that the torpedo body, with which the cars are fitted, may present an unbroken and smooth appearance without any projecting part or levers when viewed from either side. The placing of

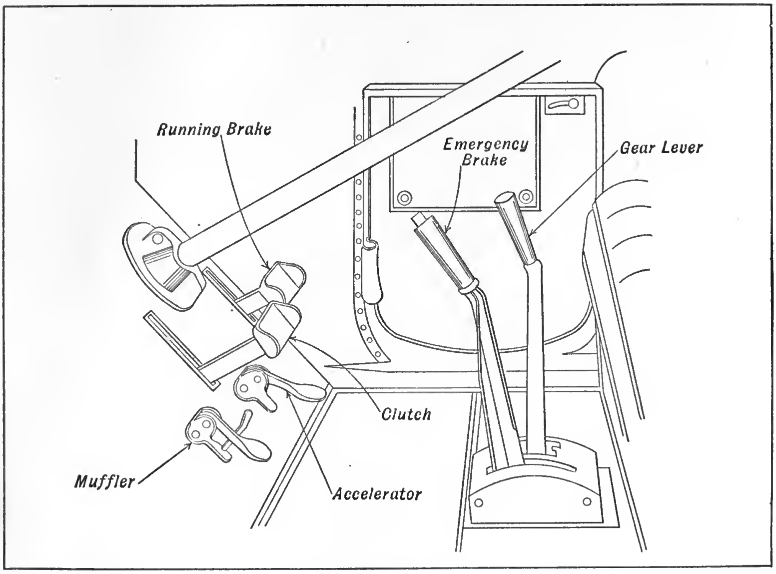


Fig. 377.—Center Control Levers of Jackson Cars and Pedals for Clutch-Running Brake, Accelerator and Muffler Cut-Out Operation.

the change-speed and emergency-brake levers on the latest Knox cars is shown at Fig. 375. The complete control system of Mitchell cars is shown at Fig. 376. The placing of the hand levers on the Jackson car and the functions of the foot pedals are clearly depicted at Fig. 377.

The instructions given for operating one type of car with selective sliding-gear transmission applies just as well to all other forms, which are controlled in practically the same manner and which differ only in the arrangement of the slots in the guiding gate and the location and direction of movement of the spark and throttle levers. Practically the same units are used in all control systems of sliding-gear cars, i. e., two pedals and two hand levers are usually provided. One of the pedals invariably releases the clutch while the other applies the service brake. One hand lever, always the one nearest the operator, is used to shift the gears, while the one that works on a notched segment is depended upon to apply the emergency brakes.

General Driving Instructions.—The following instructions apply to all types of gasoline automobiles and may be followed to advantage by all motorists. The gear-shift lever should always be placed in a neutral position when the car is stopped, whether it is left alone or attended. Gear-shift levers should always move easily and the clutch pedal of all cars equipped with sliding-gear transmission should be fully depressed before attempt is made to shift speeds. The clutch should always be applied gradually and as slowly as possible because too sudden or harsh engagement will produce stresses that will injure the tires or mechanism of the chassis. Never allow the engine to race or run excessively fast when shifting gears, and it is well not to undertake to change speeds with either motor or car running at high speed. When changing down, i. e., from a higher to a lower gear, allow the car to slow down until its speed is about the same as that which will be produced by the lower gear ratio desired before the clutch is again engaged after the gear lever has been shifted.

If difficulty is experienced in meshing the gears do not try and force them in mesh but hold the clutch pedal out for a few minutes, let the car come to almost a stop, apply the clutch quickly, and release it at once and the chances are that the troublesome shift member will have turned to a position where it will engage more easily. Sometimes one or more of the gear teeth on the shift member or the gear with which it engages may be burred up on the edges and will not engage promptly, whereas other portions of the same members will have undamaged teeth that will easily slip into engagement.

Always drive a car slowly and cautiously until you are thoroughly familiar with the control mechanism and the methods of stopping the car. When driving up grades on the higher ratios, if the motor shows any tendency to labor, shift back into a lower gear ratio which has been provided for that purpose. Many motorists believe that the best test of a car's ability is to rush all hills, or bad spots in roads, on the direct drive. It should be remembered that the lower speed ratios were provided for use at all times when employing the third or fourth speeds might produce strains in the motor. All unusual noises should be investigated at once, as these sounds usually presage more or less serious trouble. A gasoline car should never be driven with a slipping clutch, and it is imperative that the brakes and steering gear be frequently inspected to make sure that they are in proper order.

One should never attempt to drive cars at high speeds unless the tire casings are in perfect condition and the road surfaces good. In driving on clay or muddy roads, or on wet asphalt, care must be taken in turning corners and the car should be driven cautiously to avoid dangerous side slipping or skidding. When driving on unfavorable highway surfaces always keep one side of the car on firm ground, if possible. Brakes should always be carefully applied, especially if the road surfaces are wet. An automobile should never be brought to a stop in mud, clay or sand, snow or slush, if it can be avoided. Whenever road conditions are unfavorable the smooth tread tires of the driving wheels should always be fitted with chain-tire grips to insure having adequate traction.

All motorists should familiarize themselves as much as possible with the mechanism of their cars and should be competent to make the ordinary adjustments and minor repairs before any long trips are attempted. A full equipment of tools and spare tires and casings should be carried at all times. It is well to remember that the manufacturer of the car has issued a set of instructions for its care and maintenance, and these should be followed as closely as possible because intelligent care of any piece of machinery means long life and reliable service and the automobile is no exception to the rule.

Suggestions for Oiling.—One of the most important points to be observed in connection with gasoline-automobile operation is that all parts be oiled regularly. It is not enough to apply lubricant indiscriminately to the various chassis parts, but it must be done systematically and logically to secure the best results and insure the economical use of lubricant. The most important parts are the power plant and transmission system and the engine is but one point in the car that must be properly oiled at all times to obtain satisfactory results. Some of the running-gear parts are relatively unimportant, others demand regular inspection and oiling.

A very comprehensive oiling chart is presented at Fig. 378, this showing practically all of the points that require oil as well as giving instructions regarding the character of the lubricant needed and how often it should be applied. Some of the points are governed by special instructions, these being the clutch, transmission case, timer, and rear axle. The points of the clutch which need lubricant vary with the form of clutch employed. Multiple-disk types which run in oil must be kept filled up with the proper grade of lubricant. At the other hand cone and dry-plate clutches work better without any lubricant between the surfaces. When a cone clutch is employed it is sometimes desirable to soften the leather facings with a little castor oil or neatsfoot oil, if the action is beginning to get hard. A transmission-gear case which is moderately tight can be filled with a good grade of steam-engine cylinder oil, and heavy grease should not be used if the transmission shafts run on ball bearings. A heavy cylinder oil will have sufficient viscosity to cushion the teeth of the gears against shock and at the same time it will not be too heavy to flow into the bearings and lubricate them properly.

Neither the transmission case nor the differential case on the rear axle should be filled with the heavy "Dope" widely sold, which may contain wood fiber or cork particles to make for more silent operation. If gearing is noisy it is either because it is worn or out of adjustment, and the use of nostrums and freak lubricants will not improve their operation. The rear-axle differential housing should be filled with as light mineral grease as it is possible to get, those having about the consistency of vaseline being the most desirable as lubricants. Light oils should never be used in either the transmission-gear case or in the rear-axle housing, because these will not stay in place and will not have sufficient body to cushion the gear teeth.

The only other point on the chart which needs explanation is lubrication of the timer interior. This should only be oiled when it is a roller contact form and then a few drops of dynamo, magneto, or spindle oil applied to the roll and the contact segments once a week is all that is necessary. If the timer is a form using platinum contact points it does not need any lubricant. Never use graphite grease or any heavy oil in a timer case because these will not only interfere with regular ignition by short circuiting the current, but they will clog up the timer and prevent the roller establishing proper contact with the segments.

After a car is oiled it is well to go over all the exposed joints with a piece of cloth to remove the accumulations of surplus oil on the outside of the parts which serve no useful purpose and which only act to attract and retain dust and grit. The instructions given on the chart can be followed to advantage on all types of gasoline cars, though, of course, the different constructions will have to be treated as the peculiarities of design dictate.

Winter Care of Automobiles.—While motoring throughout the entire year is not unusual, many owners of cars, especially in those portions of the country where the winter climate is exceptionally severe, put up their car for a period. If the car is to be kept in service the most important thing to do is to provide some good antifreezing compound in order to prevent the water in the radiator and cylinders from congealing. There is some difference of opinion regarding the best solution to use to prevent cracked water jackets and burst radiators. Before we attempt to answer the questions often asked regarding the best antifreezing compound, it will be well to consider the requirements of such compounds. To begin with it should have no deleterious effects on the metals or rubber used in the circulating system. It must be easily dissolved or combined with water, should be reasonably cheap, and not subject to waste by evaporation or be of such character that it will deposit foreign matter in the pipes. The boiling point should be higher than that of water to prevent boiling away of the solution at comparatively low temperature.

Solutions of calcium chloride seem to be very popular with motorists, and the writer will first discuss the use of this substance. The freezing point of the solution depends upon the proportions of the salt to the water. An important factor to be considered is that if the parts of the circulation system are composed of different metals there is liable to be a certain electrolytic action between the salt and the dissimilar metals at the points of juncture, a certain corrosion taking place, and the intensity of this corrosive effect is only dependent upon the strength of the solution. As calcium chloride is derived from hydrochloric acid, which has very strong effect on metals, and as there may be particles of free acid in the solution, a certain undesirable corrosive action may take place.

In using calcium chloride when compounding an antifreezing solution care must be taken that commercially pure salt is employed as the cruder grades will liberate a larger percentage of free acid. The mistake should not be made of using chloride of lime, which has much the same appearance, but whose corrosive action is very great. Galvanized iron tanks and cast aluminum water manifolds and pump casings prohibit the use of this salt as its destructive action is great on these metals.

It is well to test a solution of calcium chloride for acid before placing in the radiator. A piece of blue litmus paper may be obtained at any drug store and immersed in the solution. If the paper turns red it is a sign that there is acid present. Acid may be neutralized by the addition of a small quantity of slacked lime.

The solutions may be made in these proportions:

Two pounds of salt to the gallon of water will freeze at eighteen degrees Fahrenheit.

Three pounds of salt to the gallon of water will freeze at one and five tenth degrees Fahrenheit.

Four pounds of salt to the gallon will freeze at seventeen degrees Fahrenheit below zero.

Five pounds of salt to the gallon will freeze at thirty-nine degrees Fahrenheit below zero.

It must be remembered that the more salt to the solution, the greater the electrolytic effect and the greater the liability of the deposit of salt crystals, which may obstruct the free flow of the liquid.

Glycerin is usually considered quite favorably, but it has disadvantages. It often contains free acid, though the action on metals will be imperceptible in average solutions. While it does not attack metal piping to any extent it is sure destruction to rubber hose and should not be used in a car in which part of the circulation-system piping is of rubber. Glycerin is expensive and it is liable to decompose under the influence of heat and proportions added to the water must be higher than that of some other substances.

Denatured alcohol is without doubt the best substance to use as it does not have any destructive action on the metals or rubber hose, will not form deposits of foreign matter, and has no electrolytic effect. A solution of sixty per cent water and forty per cent alcohol will stand twenty-five degrees below zero without freezing. The chief disadvantage to its use is that it evaporates easily and its boiling point is quite low. Alcohol volatilizes more rapidly than water and the solution is liable to become too light as proportion of alcohol to water is concerned. The percentages required are shown in the following:

Water ninety-five per cent, alcohol five per cent, freeze at twenty-five degrees Fahrenheit; water eighty-five per cent, alcohol fifteen per cent, freeze at eleven degrees Fahrenheit; water eighty per cent, alcohol twenty per cent, freeze at five degrees Fahrenheit; water seventy per cent, alcohol thirty per cent, freeze at nine degrees Fahrenheit below zero; water sixty-five per cent, alcohol thirty-five per cent, freeze at sixteen degrees Fahrenheit below zero.

Various mixtures have been tried of alcohol, glycerin, and water, and good results obtained. The addition of glycerin to a water-alcohol solution reduces liability of evaporation to a large extent, and when glycerin is used in such proportions it is not liable to damage the rubber hose.

The proportions recommended are a solution of half glycerin, half alcohol to water. The glycerin in such a solution will remain practically the same, not being subject to evaporation, and water and alcohol must be supplied if amount of solution in radiator is not enough. The freezing temperatures of such solutions of varying proportions are as follows: Water eighty-five per cent, alcohol and glycerin fifteen per cent, freeze at twenty degrees Fahrenheit; water seventy-five per cent, alcohol and glycerin twenty-five per cent, freeze at eight degrees Fahrenheit; water seventy per cent, alcohol and glycerin thirty per cent, freeze at five degrees Fahrenheit below zero; water sixty per cent, alcohol and glycerin forty per cent, freeze at twenty-three degrees Fahrenheit below zero.

The proper proportions to be used must of course be governed by conditions of locality, but it is better to be safe than sorry, and make the solutions strong enough for the extreme that may be expected.

Oils of various kinds are often used exclusively, as it is obvious that oil and water would not form a very good mixture. They are of the character that is often used to lubricate ice-making machinery, and are made especially to withstand low temperatures. The oil will not absorb heat as readily as water, and should only be used where exceptionally good methods of cooling are provided, such as a large radiator, all metal piping and a very positive pump. This oil will attack rubber hose and gaskets, however. It would seem to the writer, from actual experience, that wood-alcohol solutions were preferable to others as combining the greatest number of the requirements of a practical antifreezing compound.

After due care has been taken with the cooling system to prevent freezing, the next point to observe is the lubrication of the motor. This will depend on the oil system used and the grades of oil which are normally employed. As a general rule it is well to use a lighter grade in the winter than that utilized during warmer weather. If the clutch is a multiple-disk member it should be filled with light oil of as high cold test as it is possible to obtain. If sight-feed glasses and exposed tubing forms part of the lubricating system or the oil tank or mechanical lubricator is carried in an exposed position it should be remembered that this part should be inspected frequently to make sure that the oiling system is functioning properly.

If an acetylene-lighting system utilizing a gas generator is fitted it is necessary that the water used in the water tank or the water jacket provided on some generators be drained off and replaced with a solution of denatured alcohol and water of the proper consistency for the degree of temperature liable to be met with. During cold weather a certain amount of difficulty is always experienced in starting the car, especially when one considers the low grade of gasoline used at the present time.

If the motor is provided with compression relief or priming cocks, a small hand oil can should be filled with gasoline and ether mixture of proportions about half and half and kept tightly corked to prevent evaporation of the volatile liquids. On a cold morning when the motor is hard to start, this liquid may be injected into the cylinders, through the priming cock or by removing the spark plugs if relief cocks are not provided and the motor will be started without difficulty. If no priming can is available one of the methods of securing gasoline shown at Fig. 379 for priming purposes may be used to advantage. At A one of the tire valve caps is utilized as a cup to remove a certain portion of gasoline from the tank. It is utilized by tying a piece of cord or wire to the end and then dropping it into the gasoline tank through the filler opening. One of these caps will hold enough gasoline to start the ordinary four-cylinder motor. Another method of accomplishing the same result is shown at B. In this a piece of

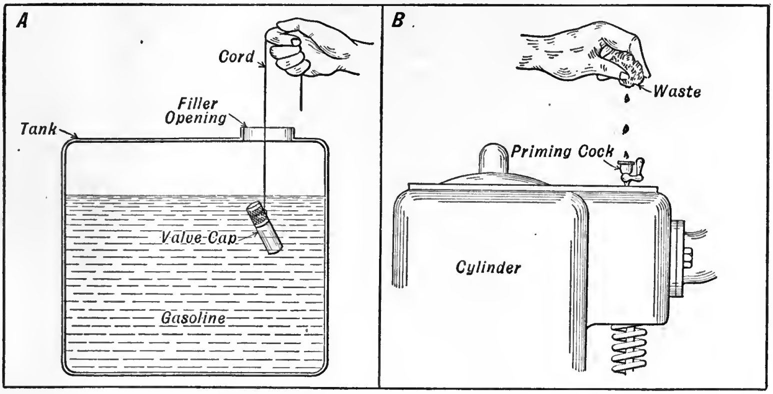


Fig. 379.—Two Methods of Obtaining Gasoline from Container to Prime Cylinders and Facilitate Motor Starting in Cold Weather.

waste is tied into a ball and dropped into the gasoline tank. When removed it is saturated with fuel and enough gasoline may be squeezed from the waste into the priming cocks to prime the motor. If an oil squirt gun forms part of the tool equipment, this may be used to draw gasoline from the tank without difficulty.

In extreme cold weather many motorists disconnect the fan belt in order that the air draught through the radiator will not cool the water to such a point that the engine will not run efficiently. Other motorists provide some form of a lined leather shield for the front of the radiator, as shown at Fig. 380. At A the shield is shown partly opened so that a large area of the radiator is exposed to the air. At B the openings in the shield have been closed by the shutter-like closure and the radiator is protected in such a way that the water will be kept warm if a stop of any consequence is made.

Spot-Removing Preparations.—A point that worries many motorists, especially those of the gentler sex, is the methods of removing oil spots which frequently are present upon the clothing of motorists. The following rules will be found valuable in this connection:

Most frequent among the various kinds of spots are those due to oil or grease. Materials in delicate colors require a special treatment so their shade will not be changed. If a grease spot is to be removed, the main portion of the grease is first carefully scraped off by means of a knife blade. A plaster of Fuller's earth, prepared by diluting the earth with a little water, is applied to the surface affected. This remains in place for several minutes, and is then scraped off. Any particles of Fuller's earth remaining on the cloth can be washed off with water. By lightly ironing out the affected portion of the garment it will be completely renovated.

In no case should a solvent (benzene or gasoline) be used for removing spots from materials dyed in light shades, as there is danger

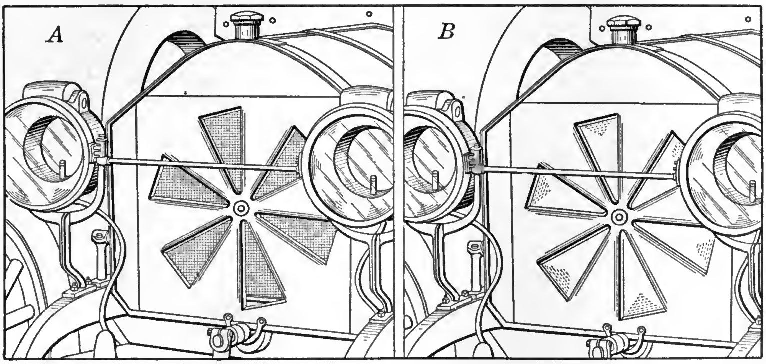


Fig. 380.—Special Cover to Protect Radiator During Cold Weather and Prevent Freezing Cooling Water. A—Slots Open for Air Passage while Car is Used. B—Radiator Completely Protected when Engine is Stopped. Cover Retains Heat and Makes for Easy Restarting.

that the dye will be dissolved with the grease. Cotton and linen garments, whether white or dyed, can be restored by local treatment with soap. Materials that are not dyed and broadcloth may be easily cleaned by means of benzol, gasoline or alcohol-benzol mixtures, the latter being the best solvent.

Material of light weight is stretched between the hands and the solvent is poured on it drop by drop until the cloth is penetrated. The degreasing process is completed by pressing the moist portion between two pieces of clean linen. If the material is heavy—such as broadcloth—the spot is rubbed repeatedly with a rag of linen soaked with one of the solvents mentioned above, until the material is moistened all through, and care must be taken to discard the rag as soon as it becomes dirty, and use a clean one.

Kerosene spots, which are easily formed, should first be treated with a slight coating of vegetable oil (lubricating oil; or, better, olive oil), so as to absorb the kerosene, and then treated with the Fuller's earth plaster, which absorbs the whole quite rapidly.

Authorities recommend a number of liquid compositions for removing grease spots from cloths which are not delicate. One of the simplest of these consists of

Wood alcohol	2 parts
Alcoholic essence of soap	2 parts
Ammonia	4 parts
Turpentine	4 parts

The alcoholic essence of soap is prepared by dissolving some white Marseilles soap in sixteen times the amount of ninety degrees alcohol, and adding ten parts of water. The white Marseilles soap is probably substantially the same as Ivory soap. Any druggist will undertake to prepare this essence. It is sufficient to apply it moderately with a linen rag.

Finally, on a road only recently tarred the motorist's clothes may be spattered with tar and their treatment is a rather delicate matter. If washable garments or fast-color materials are spotted by this material, one may, after having removed the greater portion of the tar by scraping, pour either benzol or gasoline drop by drop on the back side of the material, so the solvent will run through the spotted part. If the material is light colored it may be nearly completely cleaned by using a rag soaked in gasoline, and taking care to touch only the spot. This latter treatment calls for considerable skill, but with patience one is usually successful.

CHAPTER XIII

Practical Hints to Assist in Locating Power-Plant Troubles—Systematic Detection of Conditions to which Imperfect Operation Can Be Ascribed Faults in the Ignition System—Derangements of the Carburetion Group and Their Symptoms—Cooling and Lubrication Group Troubles.

One versed in motor-car construction and repair processes does not have any difficulty in tracing the common motor troubles to their source and the expert readily recognizes the symptoms which denote faulty action of any of the power-plant components. The average motorist, who has but little mechanical experience, is apt to become hopelessly confused when even the simpler derangements, liable to occur at any time, materialize. One who is not thoroughly familiar with motor-car construction will seldom locate troubles by haphazard experimenting and it is only by a systematic search that the cause can be discovered and the defects eliminated. In this chapter the writer proposes to outline some of the most common power-plant troubles and to give sufficient advice to enable those who are not thoroughly informed to locate them by a logical process of elimination.

The internal-combustion motor, which is the power plant of all gasoline automobiles, is composed of a number of distinct groups, which in turn include distinct components. These various appliances are so closely related to each other that defective action of any one may interrupt the operation of the entire power plant. Some of the auxiliary groups are more necessary than others and the power plant will continue to operate for a time even after the failure of some important parts of some of the auxiliary groups. The gasoline engine in itself is a complete mechanism, but it is evident that it cannot deliver any power without some means of supplying gas to the cylinders and igniting the compressed gas charge after it has been compressed in the cylinders. From this it is patent that the ignition and carburetion systems are just as essential parts of the power plant as the piston, connecting rod, or cylinder of the motor. The failure of either the carburetor or igniting means to function properly will be immediately apparent by faulty action of the power plant.

To insure that the motor will continue to operate it is necessary to keep it from overheating by some form of cooling system and to supply oil to the moving parts to reduce friction. The cooling and lubrication groups are not so important as carburetion and ignition, as the engine would run for a limited period of time even should the cooling system fail or the oil supply cease. It would only be a few moments, however, before the engine would overheat if the cooling system was at fault, and the parts seize if the lubricating system should fail. Any derangement in the carburetor or ignition mechanism would manifest itself at once because the engine operation would be affected, but a defect in the cooling or oiling system would not be noticed so readily.

The careful motorist will always inspect the motor mechanism before starting on a trip of any consequence, and if inspection is carefully carried out and loose parts tightened it is seldom that irregular operation will be found due to actual breakage of any of the components of the mechanism. Deterioration due to natural causes matures slowly, and sufficient warning is always given when parts begin to wear so satisfactory repairs may be promptly made before serious derangement or failure is manifested.

A Typical Engine Stoppage Analyzed.—Before describing the points that may fail in the various auxiliary systems it will be well to assume a typical case of engine failure and show the process of locating the trouble in a systematic manner by indicating the various steps which are in logical order and which could reasonably be followed. In any case of engine failure the ignition system, motor compression, and carburetor should be tested first. If the ignition system is functioning properly one should determine the amount of compression in all cylinders and if this is satisfactory the carbureting group should be tested. If the ignition system is working properly and there is a decided resistance in the cylinders when the starting handle is turned, proving that there is good compression, one may suspect the carburetor.

If the carburetor appears to be in good condition, the trouble may be caused by the ignition being out of time, which condition is possible when the timer is attached to the cam shaft by a set screw or the magneto timing gear to the armature shaft by a taper and nut retention instead of the more positive key or taper-pin fastening. It is possible that the inlet manifold may be broken or perforated, that the exhaust valve is stuck on its seat because of a broken or bent stem, broken or loose cam, or failure of the cam-shaft drive because the teeth are stripped from the engine shaft or cam-shaft gears; or because the key or other fastening on either gear has failed, allowing that member to turn independently of the shaft to which it normally is attached. The gasoline feed pipe may be clogged or broken, the fuel supply may be depleted, or the shut-off cock in the gasoline line may have jarred closed. The gasoline filter may be filled with dirt or water which prevents passage of the fuel.

The defects outlined above, except the failure of the gasoline supply, are very rare, and if the container is found to contain fuel and the pipe line to be clear to the carburetor, it is safe to assume the vaporizing device is at fault. If fuel continually runs out of the mixing chamber the carburetor is said to be flooded. This condition results from failure of the shut-off needle to seat properly or from a punctured hollow metal float or a gasoline-soaked cork float. It is possible that not enough gasoline is present in the float chamber. If the passage controlled by the float-needle valve is clogged or if the float was badly out of adjustment, this contingency would be probable. When the carburetor is examined, if the gasoline level appears to be at the proper height, one may suspect that a particle of lint, or dust, or fine scale, or rust from the gasoline tank has clogged the bore of the jet in the mixing chamber.

If the ignition system and carburetor appear to be in good working order, and the hand crank shows that there is no compression in one or more of the cylinders, it means some defect in the valve system. If the engine is a multiple-cylinder type and one finds poor compression in all of the cylinders it may be due to the rare defect of improper valve timing. This may be caused by a gear having altered its position on the cam shaft or crank shaft, because of a sheared key or pin having permitted the gear to turn about a half of a revolution and then having caught and held the gear in place by a broken or jagged end so that cam shaft would turn, but the valves open at the wrong time. If but one of the cylinders is at fault and the rest appear to have good compression the trouble may be due to a defective condition either inside or outside of that cylinder. The external parts may be inspected easily, so the following should be looked for: a broken valve, a warped valve head, broken valve springs, sticking or bent valve stems, dirt under valve seat, leak at valve-chamber cap or spark-plug gasket. Defective priming cock, cracked cylinder head (rarely occurs), leak through cracked spark-plug insulation, valve plunger stuck in the guide, lack of clearance between valve-stem end and top of plunger caused by loose adjusting screw which has worked up and kept the valve from seating. The faulty compression may be due to defects inside the motor. The piston head may be cracked (rarely occurs), piston rings may be broken, the slots in the piston rings may be in line, the rings may have lost their elasticity or have become gummed in the grooves of the piston, or the piston and cylinder walls may be badly scored by a loose wrist pin or by defective lubrication. If the motor is a type with a separate head it is possible the gasket or packing between the cylinder and combustion chamber may leak, either admitting water to the cylinder or allowing compression to escape.

Conditions That Cause Failure of Ignition System.—If the first test of the motor had showed that the compression was as it should be and that there were no serious mechanical defects and there was plenty of gasoline at the carburetor, this would have demonstrated that the ignition system was not functioning properly. If a battery is employed to supply current the first step is to take the spark plugs out of the cylinders and test the system by turning over the engine by hand. If there is no spark in any of the plugs, this may be considered a positive indication that there is a broken main current lead from the battery, a defective ground connection, a loose battery terminal, or a broken connector. If none of these conditions are present, it is safe to say that the battery is no longer capable of delivering current. If there is no spark at the plugs, but the spark-coil vibrator functions properly, this shows that the primary wiring is as it should be and that the fault must be looked for in either the wires comprising the secondary circuit, or at the plugs.

The spark plugs may be short circuited by cracked insulation or carbon and oil deposits around the electrode. The secondary wires may be broken or have defective insulation which permits the current to ground to some metal part of the frame or motor. The battery strength should be tested with volt or ampere meter to determine if the voltage and amperage are sufficient. Storage-battery capacity is usually gauged by measuring the voltage while dry cells are judged by their amperage. A storage battery should show at least two volts per cell, while dry batteries that indicate less than seven amperes per cell are not considered reliable or satisfactory for ignition service. If there is no vibration at the coil trembler or vibrator the trouble may be due to weak current source, broken timer wires, or defective connections at the vibrator or commutator contact points. The electrodes of the spark plug may be too far apart to permit a spark to overcome the resistance of the compressed gas, even if a spark jumps the air space, when the plug is laid on the cylinder.

If a magneto is fitted and a spark is obtained between the points of the plug and that device or the wire leading to it from the magneto is in proper condition, the trouble is probably caused by the magneto being out of time. This may result if the driving gear is loose on the armature shaft or crank shaft, and is a rare occurrence. If no spark is produced at the plugs the secondary wire may be broken, the ground wire may make contact with some metallic portion of the chassis before it reaches the switch, the carbon collecting brushes may be broken or not making contact, the contact points of the make-and-break device may be out of adjustment, the wiring may be attached to wrong terminals, the distributor filled with metallic particles, carbon, dust or oil accumulations, the distributor contacts may not be making proper connection because of wear and there may be a more serious derangement, such as a burned out secondary winding or a punctured condenser.

If the motor runs intermittently, i. e., starts and runs only a few revolutions, aside from the conditions previously outlined, defective operation may be due to seizing between parts because of insufficient oil or deficient cooling, too much oil in the crank case which fouls the cylinder after the crank shaft has revolved a few turns, and derangements in the ignition or carburetion systems that may be easily remedied. There are a number of defective conditions which may exist in the ignition group, that will result in "skipping" or irregular operation, and the following is the logical order in which the various points should be inspected; the parts which demand inspection oftenest are considered first: weak source of current due to worn out dry cells or discharged storage batteries; weak magnets in magneto, or defective contacts at magneto; dirt in magneto distributor or poor contact at collecting brushes. Dirty or cracked insulator at spark plug will cause short circuit and can only be detected by careful examination. The following points should also be checked over when the plug is inspected: Excessive space between electrodes, points too close together, loose central electrodes, or loose point on plug body, soot or oil particles between electrodes, or on the surface of the insulator.

When testing a dry battery, the terminals should be gone over carefully to make sure that all terminal nuts are tight and that there are no loose or broken cell connectors. The wiring at the coil, timer, and switch should be inspected to see that all connections are tight and that the insulation is not chafed or cracked. Defective insulation will allow leakage of current, while loose connections make for irregular operation. In testing a storage battery care should be taken to remove all the verdigris or sulphate from the terminals before attaching the testing wires. If a magneto is used there may be a short circuit in the ground wire or a poor connection at either switch lever or switch key.

The timer or distributor used with a battery-ignition system may be dirty and if the device wabbles or has loose bearings, the primary contact will be very poor. The insulating ring at the timer or distributor, or the fiber or hard-rubber bushings at magneto or timer may allow loss of current if they are cracked. If the ignition system employs low-tension sparking plates the igniter should be removed and examined with particular reference to the sparking or contact points which should be clean and free from pits or irregular projections. The bushing which insulates the fixed contact or anvil from the plate should be clean and free from oil or cracks. Wear in the operating mechanism of the igniter will cause irregular operation. A poor ground contact at a commutator of the high-tension system will cause irregular ignition.

If a vibrator coil is employed the trembler platinum contact points should be examined for pits or carbonized particles that would interfere with good contact. If defective, they should be thoroughly cleaned and the surfaces of the platinum point on both vibrator spring and adjusting screw should be filed smooth to insure positive contact. The tension of the vibrator spring should not be too light or too heavy and the vibrator should work rapidly enough to make a sharp, buzzing sound when contact is established at the timer. The adjusting screw should be tight in the vibrator bridge and when proper spring tension is obtained the regulating screw should be locked firmly to prevent movement.

If the vibrator operates satisfactorily, but there is a brilliant spark between the vibrator points and a poor spark at the spark plug, one may assume that the coil condenser is punctured. Short circuits in the condenser or internal wiring of induction coils or magnetos, which are fortunately not common, can seldom be remedied except at the factory where these devices were made. If an engine stops suddenly and the defect is in the ignition system the trouble is usually never more serious than a broken or loose wire. This may be easily located by inspecting the wiring at the terminals. Irregular operation or misfiring is harder to locate because the trouble can only be found after the many possible defective conditions have been checked over, one by one.

Common Defects in Fuel Systems.—Defective carburetion often causes misfiring or irregular operation. The common derangement of the components of the fuel system that are common enough to warrant suspicion and the best methods for their location follows: First, disconnect the feed pipe from the curburetor and see if the gasoline flows freely from the tank. If the stream coming out of the pipe is not the full size of the orifice it is an indication that the pipe is clogged with dirt or that there is an accumulation of rust, scale, or lint in the strainer screens of the filter. It is also possible that the fuel shut-off valve may be wholly or partly closed. If the gasoline flows by gravity the liquid may be air bound in the tank, while if a pressure-feed system is utilized the tank may leak so that it does not retain pressure; the check valve retaining the pressure may be defective or the pipe conveying the air or gas under pressure to the tank may be clogged.

If the gasoline flows from the pipe in a steady stream the carburetor demands examination. There may be dirt or water in the float chamber, which will constrict the passage between the float chamber and the spray nozzle, or a particle of foreign matter may have entered the nozzle and stopped up the fine holes therein. The float may bind on its guide, the needle valve regulating the gasoline-inlet opening in bowl may stick to its seat. Any of the conditions mentioned would cut down the gasoline supply and the engine would not receive sufficient quantities of gas. The air-valve spring may be weak or the air valve broken. The gasoline-adjusting needle may be loose and jar out of adjustment, or the air-valve spring-adjusting nuts may be such a poor fit on the stem that adjustments will not be retained. Air may leak in through the manifold, due to a porous casting, or leaky joints in a built up form and dilute the mixture. The air-intake dust screen may be so clogged with dirt and lint that not enough air will pass through the mesh. Water or sediment in the gasoline will cause misfiring because the fuel feed varies when the water or dirt constricts the standpipe bore.

It is possible that the carburetor may be out of adjustment. If clouds of black smoke are emitted at the exhaust pipe it is positive indication that too much gasoline is being supplied the mixture and the supply should be cut down by screwing in the needle valve on types where this method of regulation is provided, and by making sure that the fuel level is at the proper height in those forms where the spray nozzle has no means of adjustment. If the mixture contains too much air there will be a pronounced popping back in the carburetor. This may be overcome by screwing in the air-valve adjustment so the spring tension is increased or by slightly opening up the gasoline-supply regulation needle. When a carburetor is properly adjusted and the mixture delivered the cylinder burns properly, the exhaust gas will be clean and free from the objectionable odor present when gasoline is burned in excess.

If a muffler cut-out is provided the character of combustion may be judged by the color of the flame which issues from it when the engine is running with an open throttle after nightfall. If the flame is red, it indicates too much gasoline. If yellowish, it shows an excess of air, while a properly proportioned mixture will be evidenced by a pronounced blue flame, such as given by a gas-stove burner.

Defects in Oiling Systems.—While troubles existing in the ignition or carburetion groups are usually denoted by imperfect operation of the motor, such as lost power, and misfiring, derangements of the lubrication or cooling systems are usually evident by overheating, diminution in engine capacity, or noisy operation. Overheating may be caused by poor carburetion as much as by deficient cooling or insufficient oiling. When the oiling group is not functioning as it should the friction between the motor parts produces heat. If the cooling system is in proper condition, as will be evidenced by the condition of the water in the radiator, and the carburetion group appears to be in good condition, the overheating is probably caused by some defect in the oiling system.

The conditions that most commonly result in poor lubrication are: Insufficient oil in the engine crank case or sump, broken or clogged oil pipes, screen at filter filled with lint or dirt, broken oil pump, or defective oil-pump drive. The supply of oil may be reduced by a defective inlet or discharge-check valve at the mechanical oiler or worn pumps. A clogged oil passage or pipe leading to an important bearing point will cause trouble because the oil cannot get between the working surfaces. When simple compression pressure feed lubricators are employed the check valves may be defective or the container may leak. Either of these conditions will prevent the accumulation of pressure on the surface of the oil and the feed will not be positive. The sight-feed glasses may fill with oil because the pipes leading from them to the engine are full, or because the conductor is clogged with oil wax. This gives sufficient warning, however, and the oil pipe may be easily cleared by removing it and blowing it out with air or steam under pressure. It is well to remember that much of the trouble caused by defective oiling may be prevented by using only the best grades of lubricant, and even if all parts of the oil system are working properly, oils of poor quality will cause friction and overheating.

Defects in Cooling Systems Outlined.—Cooling systems are very simple and are not liable to give trouble as a rule if the radiator is kept full of clean water and the circulation is not impeded. When overheating is due to defective cooling the most common troubles are those that impede water circulation. If the radiator is clogged or the piping or water jackets filled with rust or sediment the speed of water circulation will be slow, which will also be the case if the water pump or its driving means fail. Some cooling systems are so closely proportioned to the actual requirements that the stoppage of a cooling fan will be enough to cause the engine to overheat. Any scale or sediment in the water jackets or in the piping or radiator passages will reduce the heat conductivity of the metal exposed to the air, and the water will not be cooled as quickly as though the scale was not present.

The rubber hose often used in making the flexible connections demanded between the radiator and water manifolds of the engine may deteriorate inside and particles of rubber hang down that will reduce the area of the passage. The grease from the grease cups mounted on the pump-shaft bearing to lubricate that member often finds its way into the water system and rots the inner walls of the rubber hose, this resulting in strips of the partly decomposed rubber lining hanging down and restricting the passage. The cooling system is prone to overheat after antifreezing solutions of which calcium chloride forms a part have been used. This is due to the formation of crystals of salt in the radiator passages or water jackets, and these crystals can only be dissolved by suitable chemical means, or removed by scraping when the construction permits.

Overheating is often caused by some condition in the fuel system that produces too rich mixture. Excess gasoline may be supplied if any of the following conditions are present: Bore of spray nozzle or standpipe too large, auxiliary air-valve spring too tight, gasoline level too high, loose regulating valve, fuel-soaked cork float, punctured sheet-metal float, dirt under float control shut-off valve or insufficient air supply because of a clogged air screen. If pressure feed is utilized there may be too much gas pressure in the tank, or the float controlled mechanism operating the shut-off in either the auxiliary tank on the dash or the float bowl of the carburetor may not act quickly enough.

Some Causes of Noisy Operation.—There are a number of power-plant derangements which give positive indication because of noisy operation. Any knocking or rattling sounds are usually produced by wear in connecting rods or main bearings of the engine, though sometimes a sharp metallic knock, which is very much the same as that produced by a loose bearing, is due to carbon deposits in the cylinder heads, or premature ignition due to advanced spark-time lever. Squeaking sounds invariably indicate dry bearings, and whenever such a sound is heard it should be immediately located and oil applied to the parts thus denoting their dry condition. Whistling or blowing sounds are produced by leaks, either in the engine itself or in the gas manifolds. A sharp whistle denotes the escape of gas under pressure and is usually caused by a defective packing or gasket that seals a portion of the combustion chamber or that is used for a joint as the exhaust manifold. A blowing sound indicates a leaky packing in crank case. Grinding noises in the motor are usually caused by the timing gears and will obtain if these gears are dry or if they have become worn. Whenever a loud knocking sound is heard careful inspection should be made to locate the cause of the trouble. Much harm may be done in a few minutes if the engine is run with loose connecting rod or bearings that would be prevented by taking up the wear or looseness between the parts by some means of adjustment.

As a general rule the average motorist is not sufficiently informed mechanically to undertake repairs of worn motor parts, and whenever repairs of a mechanical nature are necessary it will be much more satisfactory and cheaper to have them done by experienced mechanics or repairmen. Ordinary adjustments may be attempted by even the inexpert, but it should be remembered that nothing may be changed without a good reason existing for making the alteration. It is not proposed to discuss the various causes of noisy operation at length because the defective conditions which are evident by noisy action can usually be remedied only by skilled labor. The common defects of the auxiliary groups have been mentioned in detail, however, because these troubles may occur on the road and it is well for the motorist to be familiar with the common derangements that may result in irregular engine operation or loss of power.

It is not in the scope of a work of this nature to analyze fully the mechanical derangement and methods of restoration because a separate volume would be needed to bring these points out adequately enough to be of value. If the motorist follows the hints given in this chapter he is not likely to be stalled on the road by simpler defects which he can remedy as well as the more expert. It is well to remember that common troubles can only be located by systematic search and that causes of imperfect engine action are often located by those who do not recognize the symptoms because they follow a logical process of elimination. It must be evident that all of the defects outlined will never happen within the average experience, but the conditions defined have been named because they have occurred often enough and are sufficiently common to warrant suspicion if trouble is experienced.

CHAPTER XIV

Keeping Up the Motor-Car Chassis—Common Defects of Clutches and Gear-sets—Faults in Chain- and Shaft-Driving Systems—Troubles in Front and Rear Axles—Adjustment of Brakes—Care of Miscellaneous Chassis Components—Maintenance of Body Finish, Tops, and Upholstery.

When any defects exist in the power plant they are immediately evidenced by lost power, misfiring, overheating, or other positive indications that cannot be neglected. There are many points in the chassis that may wear and be faulty in action that will not be immediately apparent. Deterioration may exist in the power-transmission elements which will mean a serious diminution in power, but as the motor car will run more or less capably the faults are not generally known and cannot be definitely located by motorists. There are some points where wear or loose parts may directly concern the safety of the occupants of the car. For instance, any defect in either the steering gear or the brakes might result disastrously in event of failure. It is not possible to discuss all the points that may need attention or to consider at length the restoration of defective components, but it is well to consider some of the common troubles which may result in imperfect operation and which can be easily eliminated.

Common Defects in Clutches.—Considering first the member of the transmission system that will affect the efficiency of the entire assembly when deranged, it will be well to discuss the troubles common to the various types of clutches. The defective conditions that most often materialize are too sudden engagement which causes "grabbing," failure to engage properly, slipping under load, and poor release. Clutches utilizing a leather facing will cause trouble after a time because of natural wear or some defect of the friction facing. The leather may be charred by heat caused by slipping, or it may have become packed down hard and have lost most of its resiliency. The clutch spring may be weakened, or broken; this will cause the clutch to slip even if the leather facing of the cone is in good condition.

The two troubles usually met with by the motorist are harsh action, as one extreme condition, and loss of power through slippage as the other.

When a cone clutch engages too suddenly it is generally caused by the surface of the leather lining becoming hard and not having sufficient resiliency to yield to some extent when first brought into frictional contact. To insure gradual clutch application the facing should be soft and elastic. If the leather is not burned or worn unduly it may often be softened by rubbing it with neatsfoot oil. Kerosene oil is often enough to keep the clutch leather pliable and it possesses so little lubricating value that the clutch members are not liable to slip because of a reduced coefficient of friction such as often caused by the application of more viscous lubricants. Kerosene has other advantages, among which may be mentioned quick penetration of the leather and not collecting grit or gumming.

When a cone clutch slips it is usually due to a coating of oil on the frictional material that decreases the value of the coefficient of friction to such a point that the pressure of the clutch spring is not enough to maintain sufficient frictional contact between the male and female members to insure driving. The remedy for this condition is to absorb the surplus oil by rubbing a small quantity of Fuller's earth into the leather surface. When the clutch cone is in place it is not easy to reach the surface of the leather, so the first step would be to disengage or release the clutch and to place enough of the Fuller's earth on a piece of paper or card so it can be sprinkled into the space left between the male and female members when the former is properly released. Borax is sometimes recommended for the same purpose and when the earth or borax are not available the carbide dust or lime residue from the acetylene-gas generator may be used to advantage. If slipping is caused by weakening of the clutch spring it may be prevented by substituting springs of proper strength or by increasing the degree of compression of the weak springs by some means of adjustment if provided for the purpose.

Another annoying condition that sometimes obtains when a cone clutch is used is spinning or continued rotation of the male member when clutch-spring pressure is released. This may be the result of natural causes but it is sometimes caused by a defect in the clutch mechanism. If the bearing on which the cone revolves when disengaged seizes because of lack of lubricant the male member of the clutch will continue to rotate even when spring pressure is released. The ball-thrust bearing employed to resist spring tension may become wedged by a broken ball and this will cause the rotation of the crank shaft to be imparted to the cone member, through the spring, which must turn with the crank shaft instead of remaining stationary, as would be the case if the ball-thrust bearing was functioning properly.

On those cars fitted with multiple-disk clutches the same troubles may be experienced as with other types. If a multiple-disk clutch does not release properly it is because the surfaces of the plates have become rough and tend to drag. The plates of a multiple-disk clutch should be free from roughness and the surfaces should always be smooth and clean. Harsh engagement also results by the absence of oil in those types where the disks are designed to run into an oil bath. Spinning or continued rotation of a multiple-disk clutch often results from seizing due to gummed oil, the presence of carbon or burned oil between the plates and sometimes by a lack of oil between the members. When a multiple-disk clutch slips, it is generally caused by lack of strength of the clutch springs or distortion of the plates. To secure the best results from a multiple-disk clutch it is imperative that only certain grades of oil be used. If one uses a cheap or inferior lubricant it will gum and carbonize because of the heat present when the plates slip or it will have such viscosity that it will gum up between the plates. Most authorities recommend a good grade of light or medium cylinder oil in multiple-disk clutches where lubricant is required. In some cases faulty multiple-disk clutch action is due to "brooming," which is the condition that exists when the sides of the keyways or the edges of the disk become burred over and prevent full contact of the plates.

Faulty clutch action has often been traced to points separate from the clutch mechanism. Some cases of failure of clutch to release have been found due to imperfect relation of interlocking levers and rods or wear in some mechanical parts. If a clutch-shifting collar is worn unduly or the small pins in the rod connecting the clutch pedal with the release mechanism have worn to any extent the pedal may be fully depressed and yet the pressure of the spring depended upon to keep the parts in contact will not be reduced to any extent. Sometimes the emergency-brake lever may have an interlocking leverage to release the clutch when it is applied, and when the brake rods are shortened to compensate for wear of the brakes the change in length of the operating rods may throw out the clutch mechanism slightly and cause slipping of the clutch because the spring pressure may be partially relieved.

Derangements in Change-Speed Gearing.—As previously explained, the simplest form of gearing to obtain various speed ratios is the friction-disk type. Failure to drive properly may result from excessive oil on either the face of the driving disk or the periphery of the driving wheel, lost motion, wear or spring at various points in the operating mechanism, or deterioration of the surfaces of either driving disks or driven wheel. If trouble is experienced in a friction transmission the first point to inspect is the condition of the friction surfaces. If excessive deposits of oil have caused slipping it should be thoroughly removed with gasoline and the surface of both disk and wheel sprinkled with talc powder. If the face of the aluminum-alloy driving disk is grooved or roughened, slipping is inevitable until the disk is refaced absolutely true. The strawboard-fiber friction band of the driven wheel may "broom" out, and this will cause slipping because the surface is not true. As a general rule, the fiber ring of the friction transmission should be renewed after it has been used from 2,500 to 3,000 miles. Wear at the countershaft bearings will produce a tendency for the driven wheel to crowd toward the center or edge of the driving disk, depending upon the relation of the actual line of contact with the theoretical contact line drawn through the disk. Lost motion or spring in the parts serving to engage the friction surfaces will cause slipping because the degree of pressure necessary to secure the frictional adhesion required between the members to secure positive driving will be reduced.

The chief trouble with a planetary transmission is caused by slipping clutch bands. These are provided with adjustments that can be tightened in case of wear and should grip positively. If either the slow or reverse bands are adjusted too tight they will bind on the drums and produce friction, which in turn will decrease the efficiency of the drive. Noisy action of planetary gearing is usually caused by lack of lubrication or excessive wear in the gearing. If the oiling is properly taken care of this condition will be practically eliminated. Sometimes the high-speed clutch may slip, but most planetary gears are provided with adjustable clutches so any wear may be readily taken up.

When sliding-gear transmissions are used the most common defect is difficulty in shifting gears and noisy operation. The difficulty met with in gear shifting is usually caused by the edges of the teeth of the shifting members having burred over so that they do not pass readily into the spaces between the teeth of the gears they engage with. Another cause of poor gear shifting is deterioration of the bearings which may change the center distances of the shafts to a certain degree, and the relation of the gears may be changed relative to each other so they will not slide into mesh as freely as they should. Noisy operation is usually due to a defective condition of lubrication, and if the gears are not worn too much it may be minimized to a large extent by filling the gear case with oil of sufficient consistency to cushion the gear teeth and yet not be so viscous that it will not flow readily to all bearing points. A difficulty in shifting is sometimes due to binding in the control levers or selective rods, and these should always work freely if prompt gear shifting is required. If considerable difficulty is experienced in meshing the gears and the trouble is not found in the gearset, it will be well to examine the clutch to make sure that the driven member attached to the gearset main shaft does not "spin" or continue to revolve after the foot pedal is depressed.

Faults in Chain- and Shaft-Driving Systems.—While power transmission by chains is not as common at the present time in pleasure-car practice as it has been in the past, side-chain drive is used to considerable advantage in motor-truck work so the following hints on chain care and adjustment will prove timely. Much of the trouble experienced when chain drive is employed can be traced to faulty design as a basis. The teeth of the sprockets may not be properly shaped and may not be of the form best adapted for the chain designed to run over them. As most chains are exposed and run without a covering of any kind, the action of the road dust and gravel is to combine with the grease often rubbed on the outside on the pretext of oiling the chain and form an abrasive that will produce rapid wear between chain and sprocket and the various links of which the chain is composed.

To obtain the best results from chain drive the chains must be maintained in correct adjustment by the radius rods provided for the purpose. If a chain is allowed to run too loose it will "whip" and is liable to climb the teeth of the sprocket. If the chain is adjusted too tight, there will be a strain on all parts and it is liable to "snap" when it leaves the sprocket, especially if the teeth are worn hook shape. A safe rule to remember when adjusting chains is to have them tight enough so that it is not possible to raise it from the first tooth with which it meshes on either sprocket, even with the aid of a lever such as large screw driver or tire iron.

Chains must be kept clean and properly oiled. The best method of removing the dirt is to take the chain off the sprockets and let it soak long enough in a large pan containing kerosene so all the dirt and gummed oil is removed thoroughly from all the interior bearing surfaces. It should be gone over thoroughly with a stiff bristle brush until each link works freely. The chain is then immersed in a pan of gasoline to remove any small particles of grit that the kerosene may have failed to dissolve. After the gasoline bath it is wiped with a clean cloth until it is dry and clean. The proper method of chain lubrication is not generally understood and in many instances it is accomplished by coating the outside of the chain with a graphite-grease combination that serves no useful purpose, and acts merely as a collecting agent for dust and grit. The proper method of chain oiling is by immersing the cleaned chain in a molten mixture of tallow or mineral grease and graphite. The entire chain is immersed in this mixture, which is kept hot so it will penetrate all the minute interstices of the chain links and produce a thin coating of lubricant at all the working surfaces. The chain is removed from the bath of lubricant and while still hot all surplus oil is wiped off until the outside of the chain is dry and clean. This method insures proper lubrication of the many small joints usually neglected and should be done every thousand miles.

But little trouble is experienced with shaft-driving systems because the driving gearing and universal joints are so well enclosed on modern axles. The bevel-driving gears are packed in lubricant as a rule, and but little wear is noted, even after several seasons of use. An important point to observe with all forms of axles is to make sure that the antifriction bearings are kept properly cleaned and oiled. The oil used should contain no acid and should be of the best quality. Care should be taken in washing the car so that water will be prevented from entering the bearing points. If the bevel gears of the rear axle grind it is due to improper adjustment or excessive wear between the teeth. Grinding sounds usually result from meshing the gears too deeply, while loose adjustment is manifested by rattling.

Care of Front Axles and Steering Connections.—The wheels of front axles, especially on the lighter runabouts fitted with ball bearings of the pressed steel cup and adjustable cone type, should be carefully examined from time to time. As a general rule, the wear upon the cones of such bearings is rapid because of the stresses obtaining at this point. It is well to jack up the axle from time to time and turn the wheels by hand to insure that they turn freely, and to move them to see if there is any play or loss motion that would indicate either wear or poor adjustment of the bearings. When examined the balls should be perfectly round and smooth and the cones and races should have unbroken surfaces. Care should be taken in adjusting the cone so the wheels turn freely and yet they should be tight enough so no play will exist between the front wheel and the bearings. If the cones are adjusted up too tight the balls will be wedged in such a way that they will soon cut into the race ways. As a general rule, annular ball bearings will need but little attention. The steering knuckles should be looked over to see that the spindle bolts are right, and the various joints of the drag link and tiebar should be carefully examined for any lost motion. It is desirable to encase all the small joints forming part of the steering system in small leather bags packed with lubricant, because if these joints are kept well oiled and protected from grit there will be but little wear at those points.

Adjustment of Brakes.—The means of adjusting brakes may be easily ascertained by inspection. If brakes do not hold properly and the friction facing is in good condition and free from oil, the failure to grip the drum is probably due to wear in the operating leverage. On some form of brakes, notably those which are expanded by a toggle joint or cam motion, compensation for wear of the brake shoes is often made by shortening the rods running from the brake to the operating lever. External brakes are usually provided with an adjustment on the brake band, which permits one to draw the ends of the band closer together and take up much of the lost motion between the band and the brake drum. When adjusting brakes it is necessary to make the adjustment so the brakes will take hold together. If one member is adjusted so that it will grip its drum before the other does, there will be considerable strain on the tires and a tendency to side slipping every time the brakes are applied. After the brakes are adjusted it is well to jack up the axle to make sure that the wheels turn freely and that there is no binding between the brake members and the drums on the hubs. If the brakes are adjusted too tightly the friction will cause heat after the car has been run a short distance, and this increase in temperature is a very good indication of power loss by friction between the brake and the drum. If the brakes are not adjusted sufficiently tight a full movement of the pedal or hand lever will prove inadequate to apply the brakes tight enough to stop rotation of the wheels. The bearings used in rear wheels are usually of the nonadjustable antifriction types and require practically no attention except to keep them properly oiled and cleaned.

Care of Miscellaneous Chassis Components.—A common trouble with all types of motor-car frames is that after a period of use they may sag down at the center. This condition may produce difficulty in clutch shifting or gear actuation because it may cause cramping or binding of the operating mechanism. A sagging frame is usually strengthened and brought back into place by a strut rod and turn buckle arrangement which may be installed under the defective member by any competent mechanic. The various frame members sometimes become loose owing to the play in the rivets caused by the frame distortions. Another point of importance is lost motion in spring hangers and shackles and often the bolts passing through the spring eye and the shackle links may be found worn half through if inspected after a season's use. On many cars no provision has been made for lubricating these points and the deterioration produces squeaking and rattles when the car is operated over rough roads. If the spring action is harsh and if these members squeak the spring leaves should be pried apart after the spring clips have been loosened a trifle and oil introduced between the leaves.

Back lash in the steering mechanism is often a source of annoyance to motorists, but if it is present only in the reduction gears at the bottom of the steering posts it is not a serious defect. On some types of worm and worm-wheel gears the worm-wheel shaft is provided with eccentric bushings and a certain amount of wear may be taken up by turning these so that the gear teeth are brought into closer relation. In cases where the control-lever rods go down through the center of the steering column accumulations of rust will sometimes cause stiff action. This condition is easily remedied by removing the rod and surrounding tube member, cleaning out the rust, and putting the parts back after they have been thoroughly oiled.

The suggestions given in this chapter and the preceding one should prove of value to all motorists by assisting them in securing a knowledge of the more common troubles incidental to motor-car operation. The general suggestions given cannot be considered applying to any specific case because they are so general in character, and obviously the differences in construction of the various cars will have to be taken into consideration in attempting to apply the suggestions given advantageously. Enough of the ordinary defects have been mentioned so that almost any ordinary derangement can be located and remedied.

Maintenance of Body and Upholstery.—Many motorists are at loss to understand the reason for quick deterioration of the brightly varnished surfaces of a motor-car body that has been in use for some time. The paint may be blistered or cracked or the finish may be spotted at various points. Bodies that were formerly black will assume a bluish tinge and bright varnish will soon become dull. If the car is an expensive one, the motorist is justified in expecting a degree of finish that will endure, but those who purchase cheaper cars must expect to lose the bright finish after the car has been used for a time. Where cars are manufactured in large quantities, the varnish is often applied before some of the under coats are thoroughly dried, and the result will be a series of blisters. Another result of hasty manufacture and of putting the car in service soon after painting is spotting. This is produced by dry mud which extracts some of the oil or gum from the varnish and may often be caused by actual chemical action of alkaline mud. The mud of city streets, especially at points where there is a great deal of animal traffic, is highly charged with ammonia, and in certain clay or lime districts the mud is very destructive to the varnish luster.

Even when a car has been properly varnished and finished there are many conditions for which the motorist is directly or indirectly to blame which will ruin even the highest grade of paint and varnish. For instance, when cars are cleaned at garages various soaps and washing compounds are used which contain alkaline materials to assist in removing dirt and oil but which are very destructive to the highly finished, varnished surfaces. Most of the soaps upon the market contain ingredients which have a chemical action on the oils of paint and causes it to deteriorate. There are soaps which do not damage painted surfaces, but these are usually more costly and require more care and labor to remove the dirt accumulation so they are not apt to be generally used. The grades of soap that act the quickest in cutting grease are those that will more quickly dull the surfaces of the body.

Some very good carriage painters go so far as advising that no soap be used on finely varnished surfaces. Some painters advise against dusting off a car and claim that accumulations of this substance should be removed from the surface by washing. It is contended that wiping off the dust will have the effect of scratching the varnished surfaces and that the best method of removing either dust, mud, or dirt, is to flush the surfaces with water from a hose. After as much of the dirt has been removed by this method as possible a sponge may be used, but care must be taken that no grit is permitted to collect beneath the sponge and that the stream of water from the hose be always kept at work ahead of the sponge.

If any grease is present on the running gear it should be removed with gasoline or benzene, and while these substances may deaden the varnished surfaces temporarily the blemish will not remain if the dull varnish is polished with a clean soft cloth wet with linseed oil. The finish of many automobiles is ruined by allowing accumulations of oil or asphalt from freshly tarred or oiled roads to remain on the body work. These substances should not be allowed to remain any longer than possible, and if the oil or asphalt has become hardened, it may be dissolved by using naphtha, vaseline, or even butter. After the oily accumulations have been dissolved the car should be very carefully washed to remove all traces of the oily mud or the solvents.

Of course there are portions of the car where it is difficult to have the paint stay in good condition. The paint is often burned off that part of the hood on a gasoline machine adjacent the exhaust pipe or on those portions of the hood of a steam car which cover the boiler or burner. Any part of the hood subjected to considerable heat will become discolored after a time and if the heat is intense the paint will burn and blister. If care is taken to keep the body properly washed by using only the best grade of carriage soap obtainable and only clean water, sponges, and chamois cloths, the body finish will be preserved for a much longer time than if washing is neglected and the mud or dirt allowed to dry on the varnished surfaces. The use of quick-acting soaps should be avoided as much as possible and tar or oil accumulations should be removed as soon as conditions will permit. If a car is kept in a barn or shed housing horses or cattle, or adjacent to a stable the fumes of ammonia will soon cause deterioration of the paint and varnish. One should never touch dusty surfaces with the hands or attempt to remove the dust by brushing off with a cloth. As a general rule, an automobile body will need to be gone over every season. The first year that the car is in use the paint should be in good enough condition, if proper attention has been paid to washing, so that a coat of varnish will suffice to restore the body to its pristine brilliancy. A car that has been used more than one season will need both painting and varnishing to make a good job.

The matter of cleaning and caring for tops and upholstery is also one that should be considered to some extent. Mohair tops are usually fitted to high-grade cars, leather to medium-priced cars, and imitation leather or pantosote on the cheaper cars. In cleaning mohair tops, it is necessary to remove not only dust and dirt but particles of grease or oily matter thrown up against it by the wheels from either the road surface or portions of the mechanism. Dust should be removed with a moist sponge, while grease or oil stains can be taken off by a sponge and good soapsuds. Leather and imitation-leather tops should be treated with some form of preservative. Some dressings may be purchased all ready mixed and may be applied by the motorist himself. Others may be prepared at very little expense. Shabby leather may be made to look brighter by rubbing over the surface with either linseed oil or the well-beaten white of an egg mixed with a little black ink. Before applying any type of dressing, it is advised to go over the surface with neatsfoot oil until it has been properly softened, and often the oil treatment will be sufficient for all practical purposes.

The following recipe is given as a good preservative for leather. It is composed of six parts of spermaceti, eighteen parts of beeswax, five parts of asphalt varnish, five parts black vine twig, two parts Prussian blue, one part nitrobenzol, one part powdered borax, and sixty-six parts oil of turpentine. The wax is melted and the borax is added, after which the mixture is stirred until a jellylike mass is formed. In another pan the spermaceti is melted, the varnish which has been previously mixed with turpentine is added, and the mass stirred well and added to wax mixture in the other vessel. The color is the last ingredient added, this having been previously rubbed smooth with a little of the mixture. The material is applied with a brush about once a week in small quantities and is wiped well with a soft cloth to polish after application.

Another formula for giving new life to leather tops or upholstery is given as follows:

Ground Ruby Shellac	2.25 parts
Dark Resin	.91 parts
Sandaric	.115 parts
Gum Resin	.115 parts
Aniline Black (Spirit Soluble)	.115 parts
Lamp Black	.115 parts
Wood Alcohol	22.50 parts

The first step in preparing this mixture is to dissolve the sandaric, dark resin, gum resin, and shellac in the alcohol; next the aniline black is added and finally the lamp black, which has been ground to a paste with a little of the liquid, is mixed in. After the whole has been thoroughly mixed it is filtered. This is applied to the top or upholstery with a brush and is polished with a soft cloth or brush.

On genuine leather tops, upholstery, and for the leather straps holding the top a good grade of harness oil is often sufficient. The following will be found an effective mixture:

Oil of Turpentine	2	ozs.
Lamp Black	½	oz.
Neatsfoot oil	10	ozs.
Vaseline	4	ozs.

The lamp black is mixed with the turpentine and the neatsfoot oil, and the vaseline is thinned by heating it, and the ingredients are mixed by shaking together. When the mixture cools it will be in the form of a grease or paste which is rubbed well into the leather to be preserved or softened.

If a car has been used on a wet or stormy day the top should be kept up until it is thoroughly dry, as if it is inserted in the top case or folded while wet the lining might mildew or rot. In folding tops care should be taken to have the folds even and to have as few wrinkles as possible. The various bows comprising the framework of the top should be separated by small rubber pads and the whole firmly strapped together by leather bands applied at each side of the folded top frame to prevent rattle.

Upholstery is usually preserved by slip covers of various grades of cloth applied to the cushions and to the backs of the seats. As most cushions and seat backs are upholstered with leather or the various fabrics imitating it, the same dressings that have been recommended for tops may be used to advantage in treating the cushions and seat backs. In some of the higher-priced cars, especially of the closed-body form, various grades of broadcloth, Bedford cord, or other textile fabrics are used. When these become dirty they must be treated very carefully and by an experienced cleaner because ordinary methods of removing grease spots will cause unsightly discolorations of the fine fabrics. Where high-grade upholstering materials are used slip covers are really necessary. These should be kept in place at all times that the passengers are in ordinary street or business dress, but may be removed and the clean upholstering used at such times that it is desirable not to dirty the clothing as when evening clothes are worn. If the cushions or seat backs are torn, or otherwise damaged, restoration can only be made by an upholsterer or carriage trimmer. Whenever any of the preservative dressings are applied to the upholstery, it is well to wipe off all traces of the dressing very carefully in order that it will not soil the clothing.

How to Keep the Hands Soft.—The mechanism of an automobile is very dirty and the fact that this grime is very hard to remove from the hands often deters motorists from making necessary adjustments. It is not difficult to keep the hands soft and to remove dirt or grease accumulations if proper precautions are taken before the work is started. The first operation is to coat the hands thoroughly with a fine soft-soap paste and rub it thoroughly into the pores of the skin and under the finger nails before starting in to work. After a little rubbing the soap is absorbed by the pores and apparently disappears. When the repairs are completed the hands are dipped in water and a little powdered pumice stone or sawdust soaked in kerosene oil is rubbed in thoroughly until the soap is brought to a lather. The hands are then washed in the ordinary manner and the dirty soap removed from under the finger nails. As the pores are filled with soap they cannot fill with dirt and the protecting influence of the soap under the nails keeps out the dirt, which cannot collect at points where it is not readily accessible. Bran or sawdust moistened in kerosene and used in connection with ordinary soap is very good to remove the dirt without injuring the hands. Various grades of prepared hand soap may be obtained on the market but most of these contain ingredients which injure the skin. Strong alkalies are used in many cases to remove the dirt and such compounds should not be used if they discolor the can in which they are sold. Any substance that will have a strong enough chemical action on metal to corrode it is not fit to be used on the skin.

A Few Words of Caution in Conclusion.—In order to obtain the best results from an automobile it is imperative that the owner familiarize himself with all the details of its operation unless he is sufficiently wealthy to hire help to drive and look after the car. All car owners who expect to look after their own machines must first acquire a knowledge of all details of the oiling system and the various points of the chassis that require oiling. More machines wear out because of lack of proper attention to lubrication than because of the amount of work done, as present designs of modern automobile parts are thoroughly reliable and can be depended on to give satisfactory service for many thousand miles without mechanical deterioration. These results can only be obtained if care is taken to keep every moving part clean and properly lubricated.

The rules given for the proper care of tires should be followed to the letter because the item of tire maintenance is one of the most costly of all the expenses incidental to motor-car operation. Careful driving and the judicious control of the car will do much toward maintaining efficiency of the mechanism and it is well to remember that more harm can be done to the various chassis parts by a fast run of a few hundred miles than will result from thousands of miles of slower driving. It is well to drive cautiously at all times and to remember that other users of the highways have rights that must be respected. When operating a car on rough roads the speed should always be reduced to a low point, and usually the comfort of the passengers will provide the best indication of whether the car is being operated at the proper speed or not.

As soon as any parts are defective and repairs are necessary that cannot be made by the motorist himself the work of restoration should be given to a competent mechanic even if his charges are higher than those having less experience. At the end of every active riding season and before the inception of the new period of service the car should be thoroughly overhauled, and one who is able to appreciate the value of this work of restoration and who takes care of the mechanism always has a machine that is in good running order and that will give satisfactory service. Many motorists are short-sighted because they neglect the mechanism and run the machine as long as it will hold together. As a rule, these are the pessimists who hold that automobiles are an unreliable and costly possession.

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