Cyclopedia
of
Automobile Engineering

A General Reference Work on

THE CONSTRUCTION, OPERATION, AND CARE OF GASOLINE, ELECTRIC, AND STEAM AUTOMOBILES, COMMERCIAL VEHICLES, MOTORCYCLES, LIGHT CARS, AND MOTOR BOATS; TYPES OF AUTOMOBILES; EXPLOSION MOTORS; DRIVING; TROUBLES; GARAGES; REPAIRS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

FIVE VOLUMES

CHICAGO
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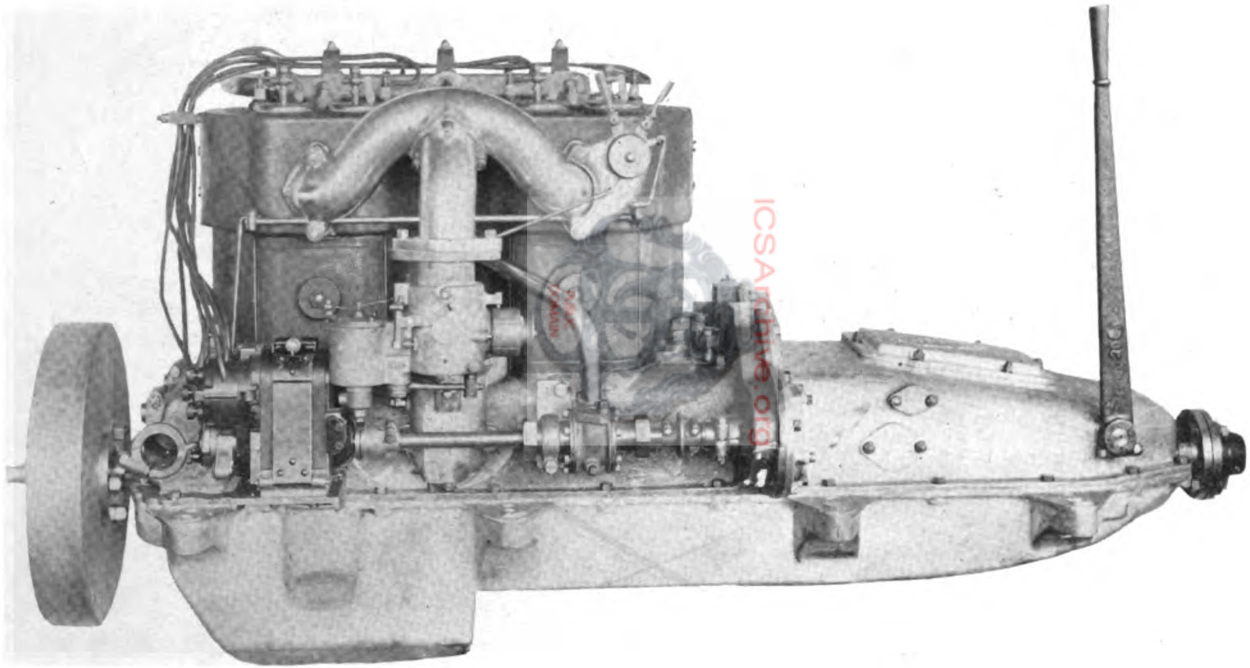

VAN BLERCK 65-HORSEPOWER FOUR-CYLINDER MODEL "E" MARINE MOTOR
Courtesy of Van Blerck Motor Company, Monroe, Michigan

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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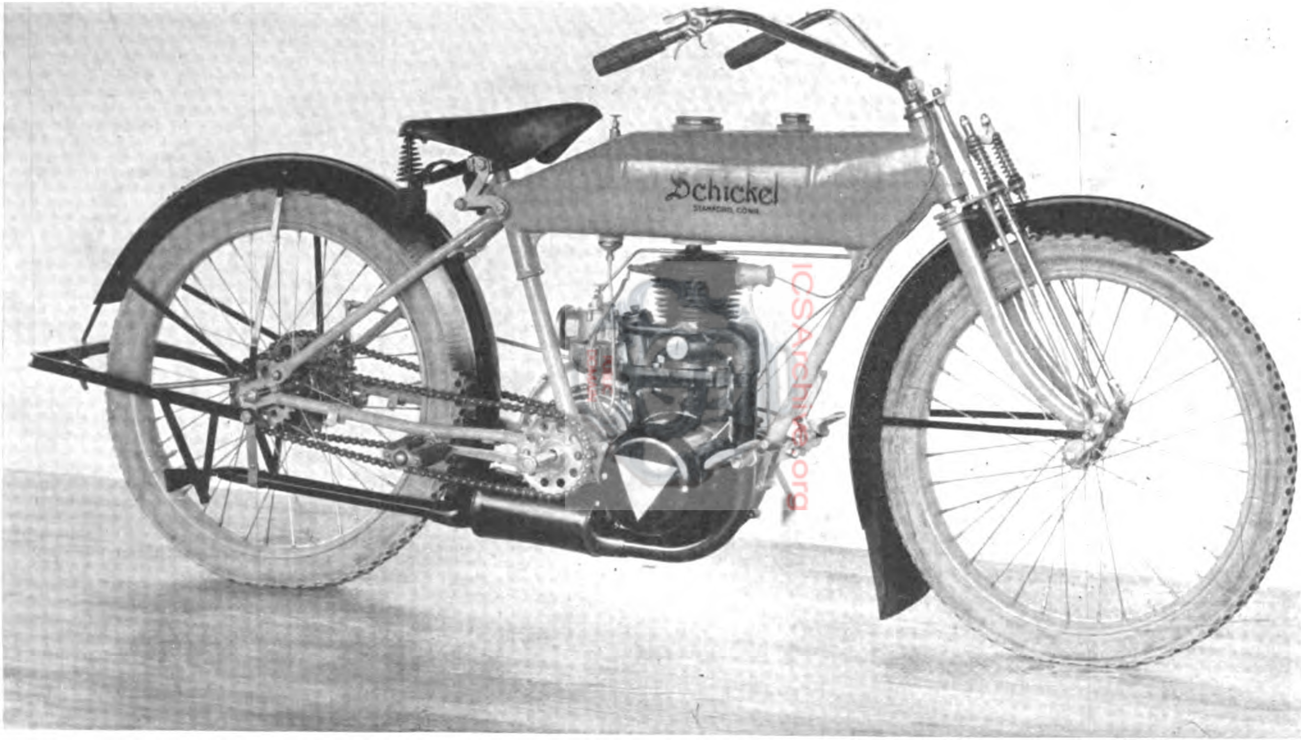
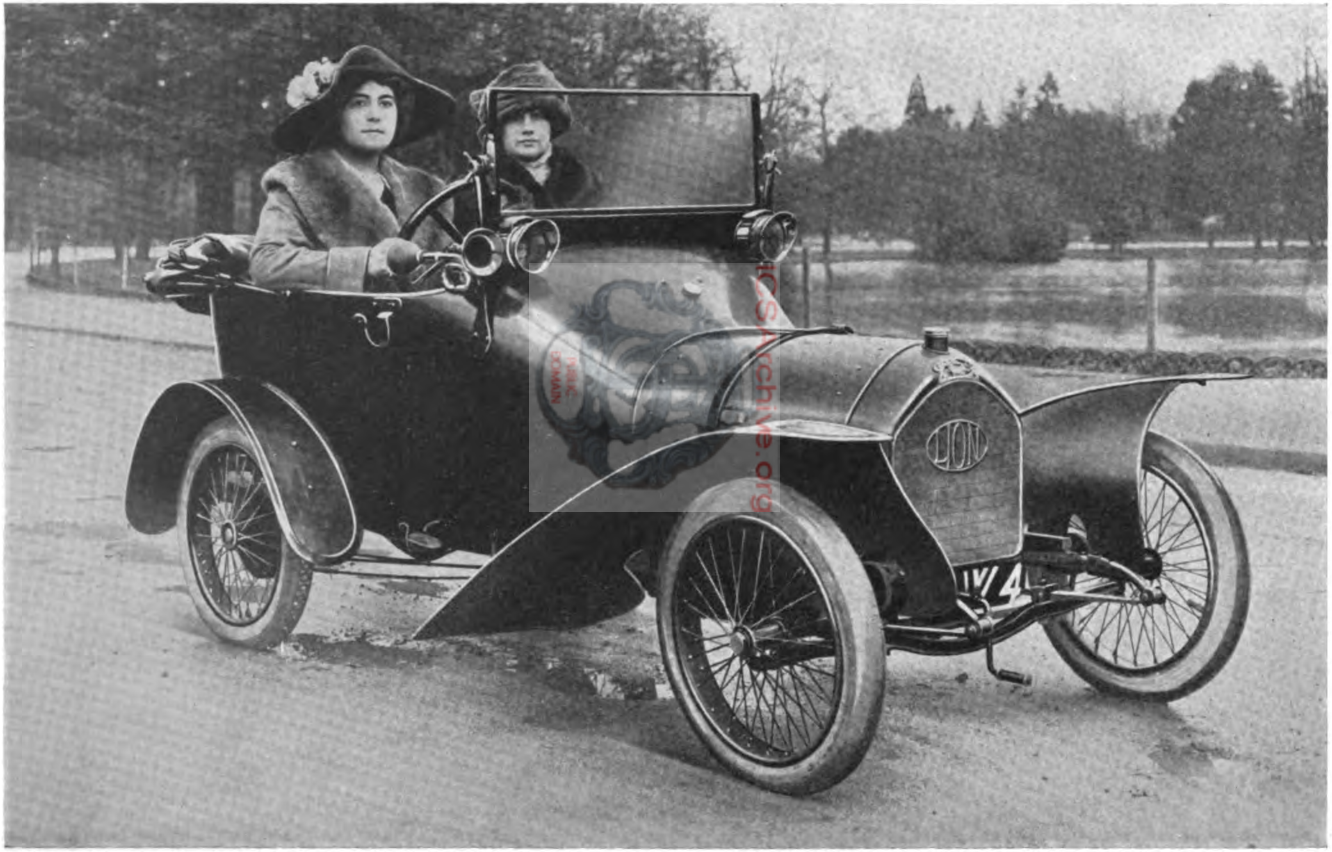


SCHICKEL MOTORCYCLE EQUIPPED WITH 6-HORSEPOWER SINGLE-CYLINDER VALVELESS MOTOR
Courtesy of Schickel Motor Company, Stamford, Connecticut



VIEW OF "BABY" PEUGEOT (FRENCH) CYCLECAR

Foreword

WITHIN recent years the internal-combustion motor and the self-propelled vehicle have become such important factors in the evolution of industrial, commercial, and social life, that a distinct need has been created for an authoritative work of reference on this subject. Such a work should treat of the results and methods of the latest approved practice in the construction, care, and operation of the various types of motor cars and other vehicles driven by gas, electricity, and steam, and of the allied branches of this rapidly developing field of apparently unlimited possibilities. It is the purpose of the Cyclopedia of Automobile Engineering to fill this acknowledged need.

¶ The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of types of mechanically-propelled road carriages and motor boats, is a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Today the automobile is a wonderfully reliable and efficient machine. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced novice, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. Astonishing refinements in the ignition, starting, and lighting systems have been lately effected, thus adding not only to the reliability of the electrical equipment of the automobile but adding greatly to the pleasure in running the car. With the possibility of extending the electrical control to the shifting of gears and other important functions, the electric current assumes a much more important position in connection with the gasoline automobile than heretofore. Altogether, the automobile as a whole has become standardized and, unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ In so far as the results just referred to are embodied in the constructions used in the typical modern car, they are presented in these pages without any attempt at great refinement of engineering subtleties, but with all explanations essential to a working knowledge of the subject. Special stress is laid on the practical, as distinguished from the merely theoretical or descriptive, form of treatment so that these volumes will be found especially adapted for purposes of self-instruction. They are designed not only to meet the requirements of instruction for the novice and of general information for the owner of a car, but also to serve as a reference work replete with information and suggestions of the utmost practical value to the most experienced chauffeur and engineer.

¶ For purposes of ready reference and timely information so frequently needed in automobile operation and construction, it is believed that these volumes will be found to meet every requirement.

¶ Grateful acknowledgment is due the corps of authors and collaborators — engineers of wide practical experience, and teachers of well-recognized ability—without whose co-operation this work would have been impossible.

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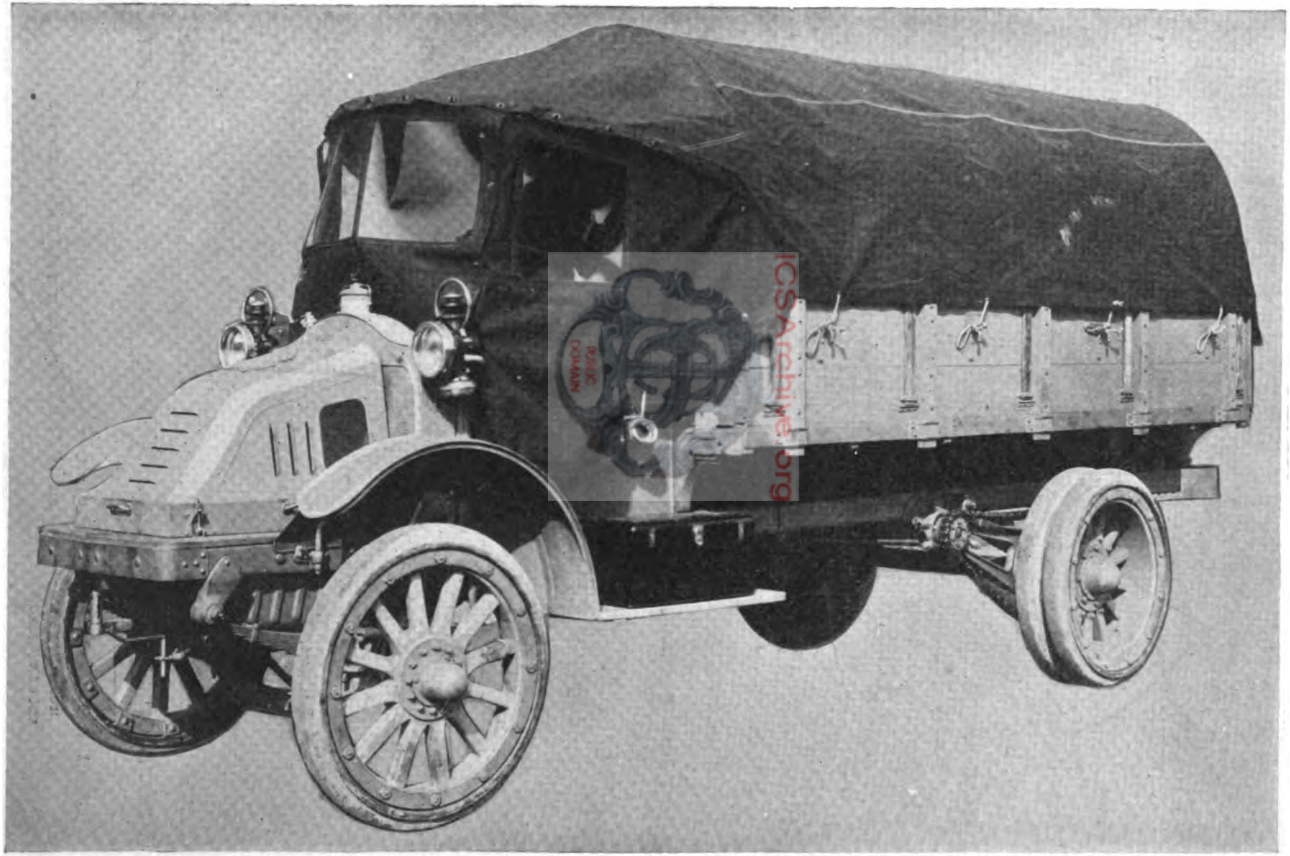


KELLY 5-TON TRUCK EQUIPPED FOR SERVICE IN THE BRITISH ARMY
Courtesy of "The Commercial Vehicle", New York City

COMMERCIAL VEHICLES

PART V

SPECIAL MOTOR-DRIVEN VEHICLES (Continued)

GASOLINE-DRIVEN TRACTION ENGINES

Greatest Field of Usefulness. Under this head falls a type of machine which might be thought of as hardly coming within the category of the commercial vehicle at all; but it represents an extremely important branch which is just beginning to come into its own and which, in the course of the next ten years or so, is destined to prove a powerful factor in the elimination of the horse from many classes of work now entirely monopolized by animal traction. Thus far, haulage has formed only a comparatively small part of the work of the gasoline traction engine and doubtless it will not be generally used for this purpose for some time to come. So far, its greatest value has been in the carrying out of purely agricultural operations on the large scale demanded by modern farming.

Strange to say, the idea of substituting the power of the internal-combustion motor for that of the horse in farming operations was first advanced in countries where the need for it was least. On the extensive farms of the Western United States horses are needed in such numbers to carry out the work that their value exceeds that of the machine which displaces them. The reverse of this, of course, is one of the greatest hindrances to "scrapping old equipment" and adopting a power vehicle of any kind. In France and England, however, where the gasoline-propelled tractor has been under development for several years, farms are small, though crops are larger in proportion. The United States has always led in the invention and manufacture of agricultural machinery, so that it was not long before attempts were made to apply the gasoline engine to this purpose. The value of machinery for such operations as plowing, harrowing, and seeding on a large scale had long been recognized in the adoption, to a limited extent, of steam traction engines, many of which are in use today. However, the disadvantages of this form of power for farm use, especially in the West, had prevented its widespread adoption. The chief of these disadvantages was the expense for fuel, as well as the difficulty of obtaining it in many sections of the country, while the low efficiency of the machine as a whole made its use impracticable even with comparatively cheap liquid fuels, such as gasoline and kerosene.

The interest taken in agricultural tractors abroad will be manifest when it is recalled that an International Agricultural-Motor Exhibition was held at Bourges, France—one of the most highly developed agricultural districts in the world—in the fall of 1908. The leading competitors in the trials held were tractors of American, British, and French makes, the last-named being of the type designed to haul the plows or other tools across the field by means of a drum and winding cable. This system had also been tried out in California and was seen to possess obvious disadvantages. It failed to score on the occasion in question, while the American tractor, true to the standing it has achieved the world over, easily carried off the honors. The machine in question was a tractor built by the International Harvester Company.

MECHANICAL DETAILS

Motor Design. Students of automobile engineering will recall that the first attempts at automobile design in this country consisted of nothing more than the adaptation of the ordinary stationary engine to a running gear, and further that it was the dogged adherence to this abortive combination that did so much to keep the American automobile so far behind its European competitors in the first years of the last decade.

The early agricultural tractors were likewise little more than stationary engines of the horizontal type, mounted on a running gear suited to the needs of the machine. The design was not as poor a one for the purpose as was the case with the automobile, since the conditions of service are totally different. Speeds are necessarily very low, as plows or other tools cannot be handled properly at a rate of travel in excess of a few miles an hour, while weight is a desideratum rather than otherwise, in order to obtain the tremendous tractive power needed to start and haul loads involving such a great drawbar pull as is required to break a number of furrows in hard soil.

The practice of simply mounting a stationary engine on wheels, which characterized early agricultural tractor design, has been practically abandoned and in its place has come a tendency to adopt the automobile motor pretty much as it stands. Between these two extremes are found motors which have been specially designed for this form of service, and which accordingly reflect the trend that future developments are apt to take better than does either of the others. Not that some of the automobile type of motors have not

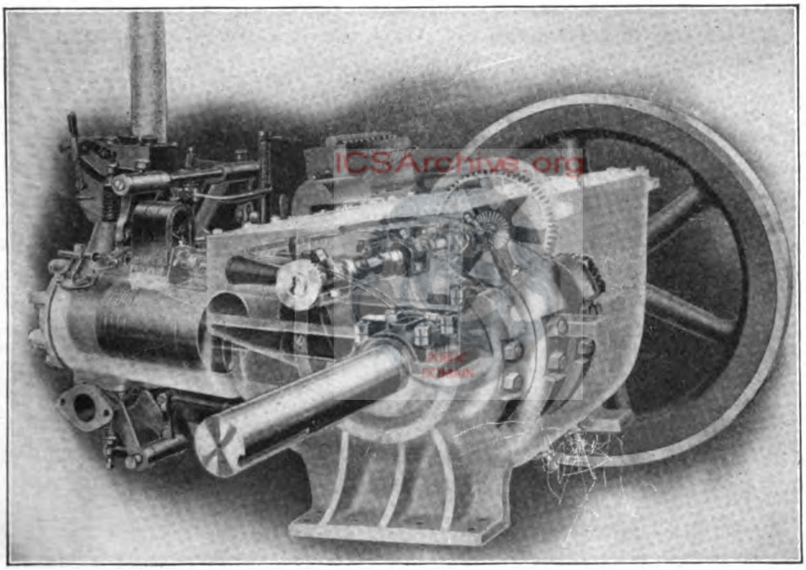


Fig. 297. Secor Kerosene Engine of Rumely Tractors

been specially built for the purpose, which is probably the case in most instances where they are used; but it is to be questioned whether the light, high-speed type of motor is the best form of power plant for such heavy, slow-moving machines.

Rumely Kerosene Motor. The agricultural tractor, to be generally adopted, must be capable of operating on a cheap and universally obtainable fuel. At present, the only fuel that fills this requirement is kerosene. Gasoline cannot be shipped on passenger steamers, while railway freight on it is so high for long hauls as to make it almost prohibitive in some parts of this country, notably in the States of the great western plains. Hence, most tractor motors are fitted to use kerosene, those employed on the Rumely tractors being designed especially for this purpose.

These motors are built in two sizes, the smaller a single cylinder 15-horsepower unit and the larger a two-cylinder, the constructional details of the last named being made plain by the phantom view, Fig. 297. They operate on the Secor-Higgins principle, which, in brief, is that of mixing water directly with the fuel, the amount being regulated automatically in accordance with the load. At the moment of explosion in the cylinder, the water is evaporated and dissociated into its elements, hydrogen and oxygen. As the piston advances and the temperature drops, some of it is converted into

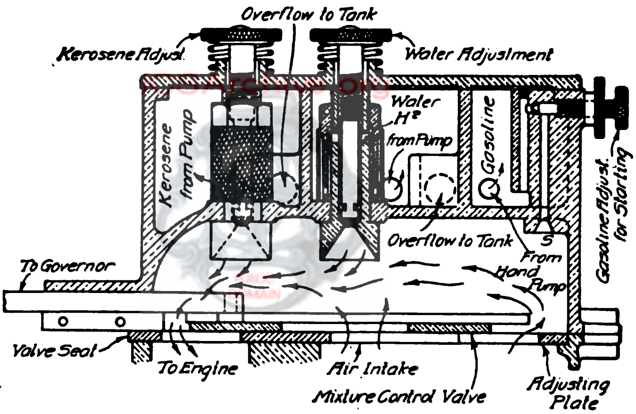


Fig. 298. Longitudinal Section of Higgins Carbureter

steam and liberates its heat, thus maintaining the pressure over a longer proportion of the stroke, so that the engine develops a high mean effective pressure on a comparatively low initial compression. In addition to facilitating the combustion of the non-volatile fuel, the nascent oxygen liberated has a high affinity for carbon and materially assists in keeping the cylinders clean, while hydrogen has a fuel value and is highly explosive when mixed with the proper proportion of oxygen, so that it also assists in the quick and thorough combustion of the kerosene.

The Higgins carbureter for utilizing kerosene is a very simple device. It consists of three compartments, one of which contains gasoline and is used for starting purposes only. The other two hold the supplies of kerosene and water, respectively, as shown in the sectional view, Fig. 298. These chambers are fitted with needle valves, by means of which the kerosene and water are fed directly into the incoming stream of air set in motion by the suction of the engine. The water is picked up first by the air current and then by the kerosene; and the resulting mixture, which is a compound of entrained globules of both liquids rather than a homogeneous fuel mixture, is passed directly into the cylinders through a very short manifold. The throttle valve consists of a sliding plate with an opening registering with the air inlet, and is designed also to close the opening into the manifold. This valve is controlled by the governor, and its movement to the right admits more air to the carbureter and more fuel to the motor, while the reverse movement cuts down the fuel supply without materially decreasing that of the air. It is therefore only necessary to adjust the needle valves for full load, as the governor takes care of all intermediate positions. This governor is gear-driven and runs in an oil bath. It may be adjusted to permit the engine to run at maximum speeds of from 300 to 400 r.p.m. The supply of kerosene and water for a day's operation is carried in tanks below the platform, and is raised to the carbureter by a small pump, the overflow running back to the tanks by gravity. The remaining essentials of the motor, such as the counterbalanced crankshaft, timing gears, camshaft, make-and-break ignition plugs, low-tension magneto, and force-feed oiler, are all plainly shown in the illustration of the motor.

Multicylinder Motors. As already mentioned, these follow the standards which have become familiar in automobile motor design. They are usually of the four-cylinder vertical type, and their construction and auxiliaries are practically identical with those ordinarily employed on automobiles. In fact, the builders of the British Daimler tractors employ the same Knight sleeve valve engine on these machines that they do on their high-priced pleasure cars. The four-cylinder motor employed on the Samson tractor is shown incidentally in Fig. 299, this illustration being chiefly intended to reveal the details of the type of transmission employed.

Transmission. In this essential a radical departure from automobile practice must naturally be followed in view of the very low speeds, usually not exceeding 2 to 2½ miles per hour for plowing, and the tremendous tractive effort that must be exerted in hauling a gang plow through heavy, wet soil. Consequently it would be out of the question to build the transmission in the form of a small gear-box, as is done on automobiles. While motors of the automobile

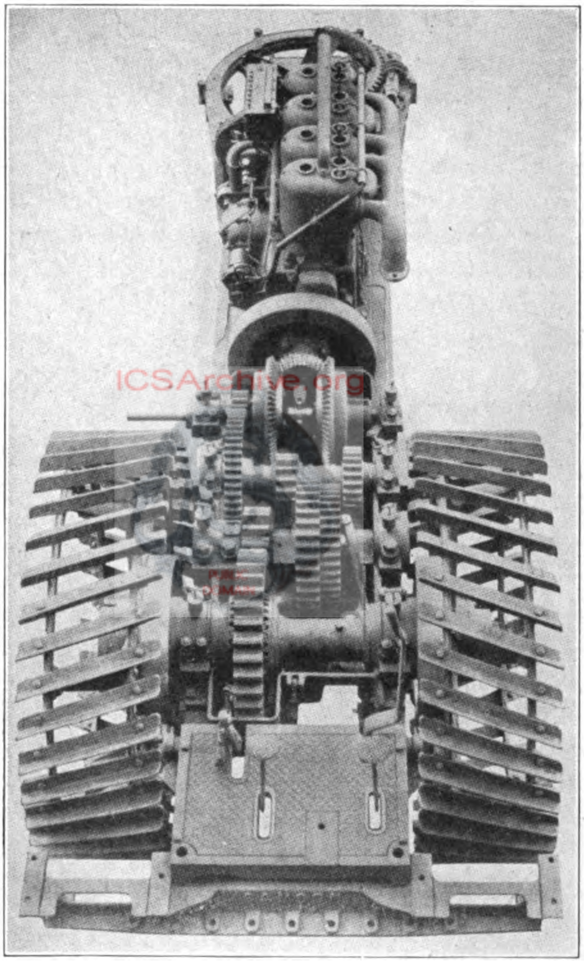


Fig. 299. Details of Transmission, Samson Tractor

type are employed, their speed is usually very much lower, the motor of the Samson tractor, for example, running at 525 to 575 r.p.m. Still, to give the two forward speeds of 2 and 4 miles an hour, it is evident that there must be a great reduction between the motor and the driving wheels, particularly as the wheels are very large and make comparatively few revolutions per mile. A double-drum expanding friction clutch is built in the large bevel gears to form the first step in the transmission, a small spur pinion on the same shaft as the large bevels meshing with a large spur gear on a transverse shaft. The latter carries two fixed gears, while a sliding pair is mounted on a parallel shaft just forward of it. When the left-hand one of these is meshed with the left-hand fixed gear, the tractor drives at 2 miles an hour through still another speed reduction between the second transverse shaft and the rear axle. By meshing the right-hand gears, the higher speed is obtained. It will be noted that there are four different steps in the speed reduction between the motor and the rear axle, and that the gears and shafts are of large dimensions.

Except for the employment of the live type of axle, which is not ordinarily used on tractors or other machines as heavy as this, the details of the Samson transmission are almost identical with those of the Daimler, on which the final drive is through large spur gears bolted to the driving wheels. In fact, it may be regarded as typical of tractor practice, having also been used for many years on steam road rollers, though in this case the bevel gears are unnecessary, as the engine is mounted on top of the boiler and carries the first spur pinion directly on its crankshaft.

Construction Details. The chassis, if it may be so termed, usually consists of a structural-steel frame, to which the motor, transmission, and radiator are directly attached above, and the tanks, steering gear, and axles below. Slow-speed vehicles of this weight are naturally built without springs. The extremely low rate of travel and the heavy duty imposed on the engine make generous cooling facilities necessary; these usually take the form of a large flat- or spiral-tube radiator built in rectangular form and provided with a hood and stack to create an upward draft through the cooling tubes. Oil is frequently employed as the cooling medium, especially for winter use. The wheels are usually of a composite type, having cast rims and hubs and staggered steel spokes, provision usually being allowed for the insertion of spikes or similar devices to give increased traction, in addition to the cleats which may or may not be a permanent attachment to the rim. In some cases, such as the

Rumely, the wheel is so designed that its width may be considerably increased when necessary to run on very soft ground. On four-wheel tractors, steering is generally by means of a worm and worm wheel, the latter being attached to a winding shaft carrying chains attached to a swiveling front truck, to which limit chains are fastened to prevent the truck from being turned beyond a certain angle, or from being forced around by the movement of the machine when at an extreme angle. A worm and sector, or bevel gear and sector, are used for steering on the three-wheeled machines.

TYPES

Rumely. The Rumely tractor shown in Fig. 300, is a close approach to what may be regarded as standard practice in this field so far as its construction details are concerned. It takes but a glance

Fig. 300. Rumely Kerosene Engine Tractor

to recognize the influence of the steam-traction engine and the steam road roller of American design. One of these machines hauling a gang plow turning eight furrows is shown in Fig. 301.

International. The International tractor is practically nothing more than one of the stationary engines of this make mounted on the platform of a heavy, four-wheeled truck, Fig. 302. The engine in question is of the single-cylinder long-stroke type with the valves in the head, the exhaust valve being mechanically operated, while the inlet valve is automatic; the governor, as is customary in stationary practice, is of the hit-and-miss type acting on the exhaust valve.

Fig. 301. Kerosene Tractor Hauling Heavy Gang Plow

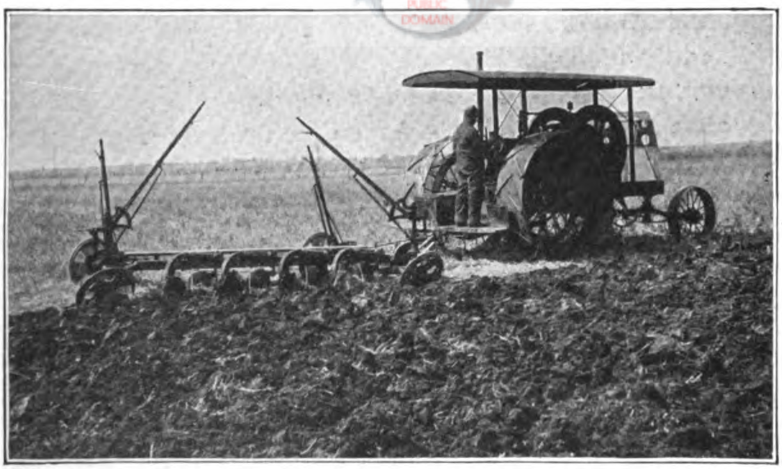


Fig. 302. Gang Plow and Gasoline Motor Tractor in Heavy Soil

In governors of this class, centrifugal force is taken advantage of to make the exhaust valve rod hit or miss the valve tappet, opening the latter or allowing it to remain open, according to the speed and the requirements of the load. As the automatic inlet valve depends upon atmospheric pressure for its operation, it cannot open unless the exhaust valve has closed on the stroke just preceding, so that no fuel enters the combustion chamber except when an explosion is necessary. As the governor is also usually designed to trip the igniter mechanism out of action at the same time, such engines are very economical of both fuel and electric current. The cylinder is of large bore, and a low compression is employed as compared with automobile motor practice, two huge flywheels being utilized to give the engine a smooth-running balance. It is cooled by means of a modified form of water tank placed forward. This is provided with a large wire-gauze screen with sloping sides, over which the hot water is sprayed immediately on leaving the water jacket; it is then collected in the tank below and circulated.

The drive wheels are entirely of metal, having 56-inch diameter and an 18-inch face; they have heavy lugs bolted to the tires to provide ample traction, even on soft ground. Two friction clutches are employed, a large one for the forward speeds and a smaller one for the reverse. The drive is through two sets of pinions and large gears, a sliding pinion on the crankshaft of the engine driving a large differential gear on a countershaft carrying two pinions at its outer ends, which engage large gears on the road wheels. Reverse is obtained by shifting a lever, which throws the large clutch out of engagement, and engages the small one driving an intermediate gear. The same lever gives both the forward and reverse speeds, while a foot lever applies a band brake operating on the differential.

The foregoing serves to describe the small-size International tractor, which is fitted with a 15-horsepower single-cylinder engine, although it generally covers the construction of the larger sizes also.

Hart-Parr. The Hart-Parr tractor, which has achieved considerable success, was one of the first to depart from the practice of employing the ordinary stationary engine as its motive power. As will be seen from the illustration, Fig. 303, the engine is of the two-cylinder horizontal type, the cylinders being placed beside each other and having all the valve mechanism in the head, which makes it very accessible. The crankshaft has the two throws placed 180 degrees apart, so that the heavy pistons are always moving in opposite directions. This gives an excellent mechanical balance and accounts for the single flywheel of greatly reduced size. The use of an auxiliary exhaust valve, or port, uncovered by the piston just before

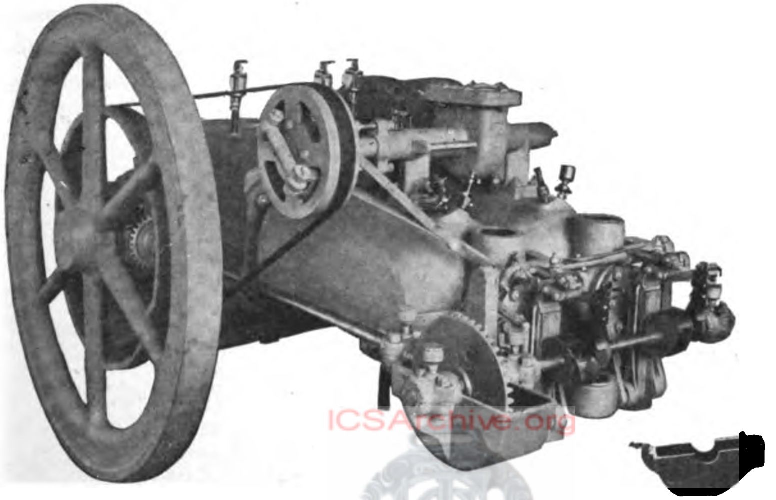


Fig. 303. Motor of Hart-Parr Traction Engine

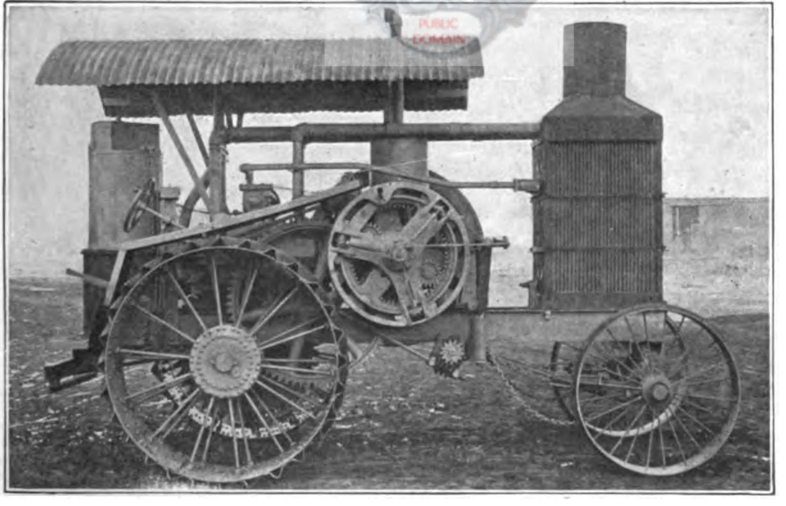


Fig. 304. Hart-Parr Traction Engine

the end of its outward travel on the power stroke, is also a feature of this engine and insures cool running under the heaviest loads.

An original and ingenious system of oil-cooling is employed, making it unnecessary to take any precautions to prevent freezing in cold weather. As will be seen from the illustration of the complete Hart-Parr machine, Fig. 304, this consists of a special type of radiator mounted on the forward end of the platform. This radiator is formed of a number of thin, corrugated sections, covered by a conical hood and a short stack. The supply of oil is circulated through these sections of the radiator and through the jackets of the cylinders by means of a centrifugal pump mounted directly on one of the cylinders.

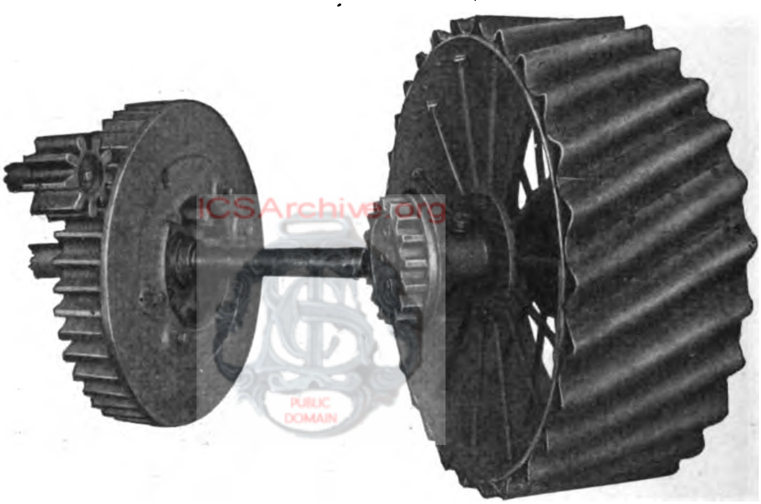


Fig. 305. Differential and Drive of Hart-Parr Tractor

The exhaust from the engine is led into the hood over the radiator, and in the upper faces of the exhaust pipes under the hood are drilled a large number of small holes, causing the exhaust gases to be discharged upward in numerous fine jets, which not only act as a muffler, but also set up a strong draft of air through the radiator. As the oil never reaches a temperature sufficiently high to boil it, and there is no waste, the original supply should last as long as the engine, barring accidents. The engine is capable of delivering 45 horsepower, according to the usual rating, but as the machine is intended to displace 22 draft horses, the tractor is given a nominal rating of the latter figure.

The driving wheels measure 66 inches in diameter and are driven through a train of gearing. Between the gearing and the engine, friction clutches are interposed, one being employed for the forward speeds and one for the reverse and both operating through a single lever. The traction gearing may be independently disengaged from the engine, the clutch-operating lever then giving a forward or reverse motion to the power pulley for driving machinery. The reversing clutch is also utilized as a brake. For ordinary traction service, the Hart-Parr engines are geared for a speed of three miles an hour and are fitted with the usual bevel gear differential. The drawbar pull required for plowing is so heavy, however, that

Fig. 306. Samson 3-Wheel "Sieve-Grip" Tractor

these engines are equipped for this service with the substantial spur-gear differential shown in Fig. 305, and are geared for a speed of 2⅓ miles an hour.

Two sizes are built, the 22-horsepower size just described, and a smaller machine having a nominal rating of 17 horsepower. The latter weighs 7½ tons, while the former is one ton heavier; the plowing engine of the higher power weighs 9½ tons. The bore and stroke are 9-inch by 13-inch in the 17-horsepower engine, and 10-inch by 15-inch in the larger size, the engines running at 280 and 300 r.p.m., respectively, and making 17.3 turns of the crankshaft to one revolution of the driving wheels. They operate 10 hours per day, doing the heaviest class of work, on a fuel consumption of 25 to 40 gallons of kerosene or gasoline, according to size.

Samson. In contrast with this, the Samson, which is built on the Pacific Coast, represents a much closer approach to a three-wheel automobile, or at least to an automobile tractor. Apart from its motor and transmission, which have already been referred to, this machine is distinguished by the use of what is termed "sieve-grip" driving wheels. These will be noted more in detail in Fig. 299, from which it will be plain that they are in reality skeleton wheels, the treads of which consist of series of angle bars riveted to

Fig. 307. Johnson Agricultural Tractor Plowing an Orange Grove

their supports in a staggered relation to one another where the two wheels are concerned, thus giving the maximum traction. One of these tractors is shown in service in Fig. 306.

Johnson. Fig. 307 illustrates a tractor of this type in service, plowing an orange grove, and shows that it differs radically from either of the foregoing. Like the Samson, it is a three-wheeler, but there the resemblance between the two ends. The engine is placed horizontally and drives through side chains and sprockets, which accounts for a large part of the speed reduction necessary. Instead of depending upon the natural movement of the air to assist in cooling the radiator, the latter is carried in a housing which contains a high-speed fan and which provides the necessary draft.

Detroit. A somewhat novel type, apparently based on the "horseless" idea in tractor design, is the Detroit, which is shown in Fig. 308, hauling a load of hay. This tractor is really a mechanical horse, in that it is not only designed to be directly attached to any farm tools or loads in practically the same manner as a horse, but is also controlled entirely by reins, of which there are three—two for steering and one for the two-speed transmission. A pull on either of the steering reins connects the engine with the steering gear through a friction clutch, and the motor's power is thus used for turning. A pull on both reins at once disengages the driving clutch and stops the tractor, while the slow or fast speed is controlled by the third rein, making the method of operation precisely the same and quite

Fig. 308. Detroit "Rein-Controlled" Tractor

as simple as driving a team of horses. In its mechanical details the machine follows standard practice, having a four-cylinder vertical gasoline motor, water-cooled, and with high-tension magneto ignition and a carbureter designed to run on either gasoline or kerosene. A 5-inch seamless steel tube is used as a "pole" or drawshaft for attachment to vehicles, plows, or other implements, while, as usual, it may be used as a portable stationary engine for running machinery.

Auto-Tractor. As the time is already at hand when even a greater proportion of the farming population boasts of automobiles than city dwellers can be credited with, this tractor has been so designed as to enable the farmer to use his car for actual farm work in addition to its other services. The tractor accordingly consists simply of a long steel frame, a pair of standard steel tractor wheels fitted with a gear drive, and a standard automobile radiator, as will be seen in Fig. 309. The only modification required on the automobile itself is the fitting of a pair of small spur gears to the rear

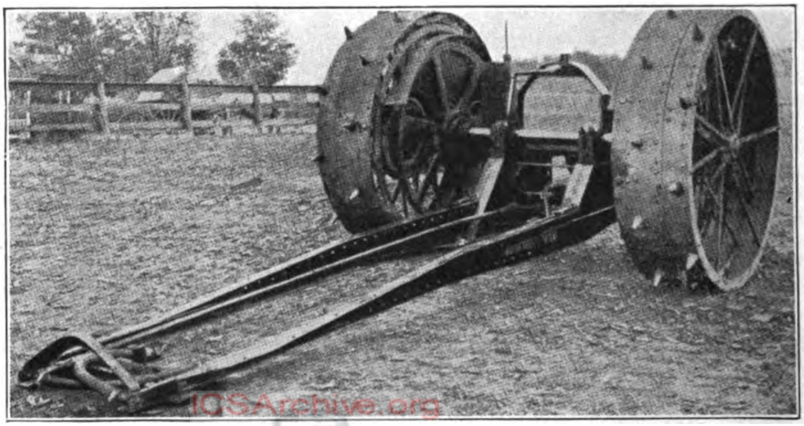


Fig. 309. Auto-Tractor Ready for Attachment

wheels. The car is backed up over the tractor frame, and ropes attached to the rear of the tractor are then passed around the hubs of the rear wheel gears mentioned. By running the car in reverse it hauls itself up the incline of the frame until the rear axle rests in

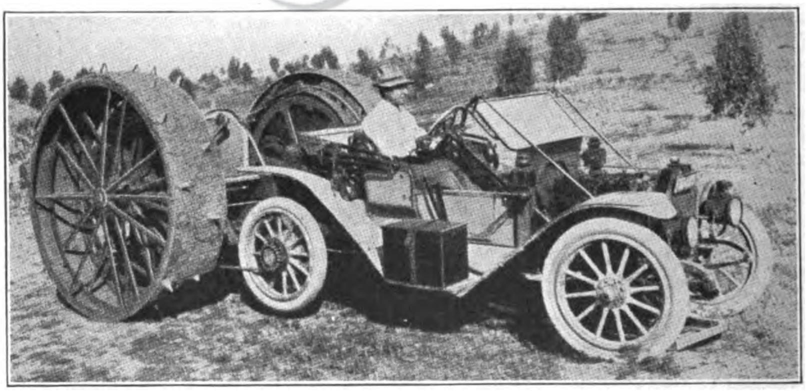


Fig. 310. Method of Mounting and Attaching an Automobile to the Auto-Tractor

bearings provided for it. At this point, the wheel pinions mesh with large spur gears of almost the same diameter as the tractor driving wheels. The front end of the tractor frame is then lifted and made fast to the forward end of the car frame, the connections of the extra radiator on the tractor are made with the cooling system of the car, and the automobile is ready to run as a tractor. Fig. 310 shows the car hauling itself into place on the tractor frame. When attached to the tractor, the automobile motor may also be utilized as a stationary engine.

In addition to the speeds available on the automobile, the tractor gearing also provides two speeds permitting the machine to travel at 2 or 4 miles per hour. The power is taken from the hub gears on the automobile close to the center of the axle instead of from the tire; and, as the weight of the car is entirely removed from the rear axle and there are no road shocks, the most injurious fea-

Fig. 311. British Daimler Tractor Hauling 8½ Tons up Grade

tures of ordinary automobile operation disappear. The gearing is so designed that the car is run on high speed entirely, even when starting under load, although the intermediate speeds may be resorted to in case of extra heavy pulls. This means that when the tractor is plowing at the rate of two miles per hour, the automobile engine is running at its normal speed of 800 to 1000 r.p.m., at which speed it is designed to give its best efficiency and run constantly without strain. The use of one of these tractors in an Oregon orchard is said to show a reduction from $3.40 per acre per year with teams to $1.20 per acre per year with the machine, the cost per acre for each cultivation being only 24 cents.

British Daimler. This is a design which is intermediate to the Rumely and Samson types already described, in that it has the general structural features of the former and an automobile type of motor like the latter. This motor is the Daimler-Knight sleeve type as employed on the high-priced automobiles built by the same company, while the transmission is similar to the Samson except for the final drive through spur gears on the rear wheels. The high stack attached to the radiator makes it strongly resemble a steamer, as will be seen by Fig. 311, which shows the tractor hauling a load of 8½ tons up a gradient of 1 in 6. In Fig. 312 the same tractor is shown hauling a gang plow. The motor of this machine is rated at 40 horsepower at a speed of 1000 r.p.m., has high-tension magneto ignition, pump lubrication, and a centrifugal pump for circu-

Fig. 312. Plowing with a British Daimler Tractor

lating the cooling water. The exhaust of the motor is led into the stack over the radiator, thus creating ample up-draft through the tubes without the use of a fan. Two forward speeds are provided, one of 2.5 miles and the other of 4 miles per hour, and one reverse speed at the lower rate mentioned, these being based on 1000 r.p.m. at the engine. The rear wheels are 6 feet in diameter and 15 to 18 inches wide, according to requirements, and run on a solid rear axle. The differential is mounted on the countershaft and is so designed that it may be locked from the outside of the housing. A powerful winch or winding drum is mounted on the rear axle with fair leads at the rear edge of the tractor, so that the rope may be led in any direction within an angle of 90 degrees of the longitudinal center line of the tractor.

The same company also builds a heavy agricultural tractor fitted with a six-cylinder 105-horsepower motor, which is probably the largest of its kind built as a stock machine. The details of the engine-mounting, radiator, and worm-gear drive are shown in the sectional elevation, Fig. 313. A small air compressor and storage tank are fitted and the former is utilized as a starting motor to turn

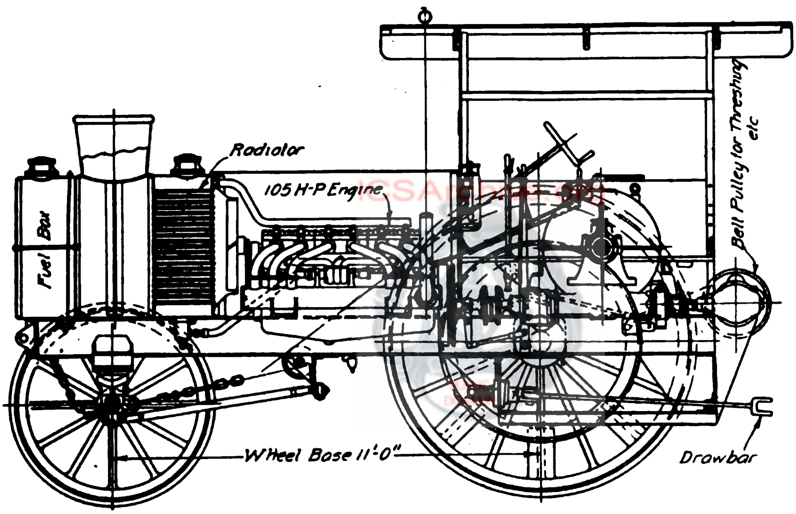


Fig. 313. Sectional View of British Daimler 6-Cylinder 105-Horsepower Tractor

the main engine over. The driving wheels of this tractor are at least 10 feet in diameter.

Holt Caterpillar Tractor. For agricultural operations in alluvial lands, reclaimed swamps, and rice fields, or other ground so soft that the wheel type would become mired, the so-called "caterpillar" tractor has been developed. Tractors of this type have been in successful operation in various parts of the world for a number of years. They are built in two sizes, of 30- and 60-horsepower. Fig. 314 shows one of the smaller size, and makes the appropriateness of the title apparent. Apart from the variation in dimensions, the only difference between the two is the provision of a forward steering truck on the large tractor, as will be noted by referring to the section on "Road Trains", and to Fig. 296, in which is shown a 60-horsepower Holt Caterpillar tractor drawing six trailers. From an engineering point of view, the Holt tractor is of more than usual interest, as it is the only form of locomotion not involving the use of wheels in contact with the ground.

As its name indicates, the tractor literally crawls over the ground by means of blunt-toothed endless chains. This must not be taken to signify that its speed is simply a crawl, as the tractor illustrated hauls a gang plow at the rate of 2½ miles an hour, plowing speeds for tractors generally being from 2 to 2½ miles an hour, regardless of type. The motor is a four-cylinder vertical gasoline engine of

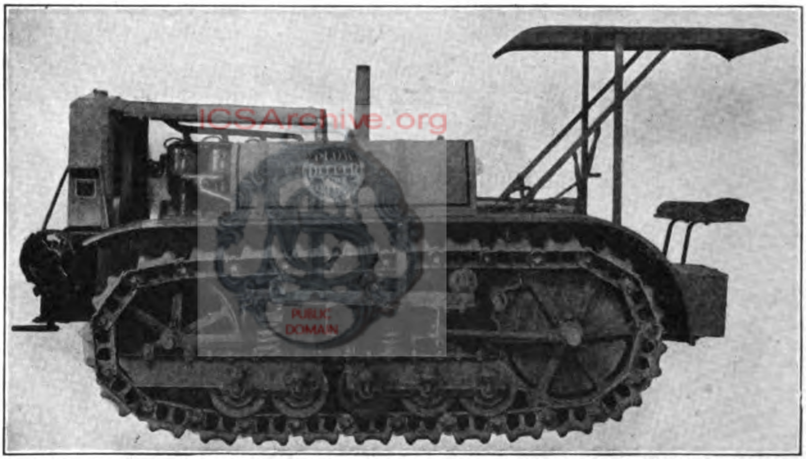


Fig. 314. Holt Caterpillar Tractor for Plowing

special design, the cylinders being cast independently with separable heads. The valves are placed in these heads and operated by rocker arms from a single camshaft. To provide the maximum accessibility, the crankcase is of practically the same height as the cylinders and is provided with large handholes through which the pistons can be withdrawn. In fact, the crankshaft can be taken out without disturbing the cylinders, manifolds, or ignition system. A dual ignition system, comprising a high-tension magneto for running and a battery-and-coil auxiliary for starting, constant-level splash lubricating system with an auxiliary force-feed oiler supplying oil directly to the main bearings, a Schebler carbureter, and a centrifugal pump for circulating the cooling water, constitute the motor essentials. Two flywheels are fitted, one of them being of unusually liberal diameter and weight which permits the motor to develop its rated output at the low speed of 600 r.p.m. A standard type of fly-ball centrifugal governor mounted outside the crankcase on an extension of the camshaft, and acting directly on the throttle, prevents this speed from being exceeded. The cooling system consists of a vertical tube radiator, fan, and a large water tank, the mounting of the motor and radiator being in accordance with standard truck practice.

Caterpillar Drive. From the motor the power is transmitted through a multiple-disk clutch consisting of two large bronze disks

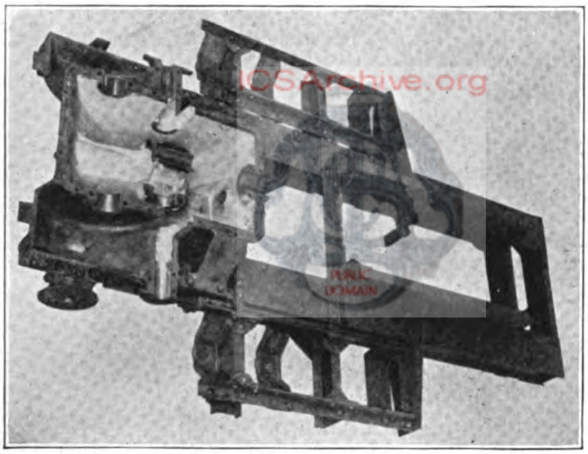


Fig. 315. Frame of Holt Caterpillar Tractor

and three of iron, the former being carried on a steel ring driven by casehardened lugs in the flywheel rim. The weight of the clutch itself is carried by a self-aligning annular ball bearing mounted on the end of the crankshaft. A heavy universal joint interposed between the clutch and the transmission takes care of any relative movement. The relative locations of the motor, clutch, and transmission can be noted in the illustrations of the frame, Fig. 315, the motor being at the right, the clutch in the opening just back of the transverse brace, while the lower half of the transmission case is bolted directly to the frame and has the bearings cast integrally. The forward, reverse, and bevel-reduction gears are located in this case, the final or main driving gears, which run in oil, being placed on each side of the housing in the broad troughs shown. A shaft extends outward from each one of these main driving gears and carries on its outer end a spur pinion meshing with a large gear on the same shaft as the sprocket, which is shown at the right of Fig. 316. Each of these sprockets is controlled by a friction clutch, so that the two driving units are operated independently, and no differential is required.

Engaging these sprockets are heavy block chains, the links or blocks having blunt teeth to give traction in moist ground. As shown in Fig. 316, the weight of the tractor is carried by five grooved steel wheels on each side, these wheels being mounted on a spring-

Fig. 316. Details of Caterpillar Drive

supported frame. On the upper side of this frame are three heavy rollers to prevent the chain from the sagging due to its weight, while at the forward end it is guided around a plain idler or free-running pulley. The driving effort is taken on the straight rod, bearing on the sprocket shaft at the rear end and bolted directly to the frame at its forward end. All bearings are lubricated by grease cups. The chain links or "track shoes", which are detachable, are made heavy enough to withstand the most severe usage. They have curved ends and overlap each other, so that there is no opening between them, even when the chain or "track" is curved around the sprocket. Due to the great area in contact, there is practically no friction between the shoes and the ground, and the track cannot slip. The truck illustrated is for service on comparatively hard surfaces, its width being increased in accordance with the nature of the ground, some of the tractors being fitted with tracks 30 inches

Fig. 317. Holt Caterpillar Tractor Plowing

in width. The upper face of the shoes forms a smooth steel track on which the five weight-carrying wheels run. The rails of the caterpillar track are made high and have openings at the side, so that

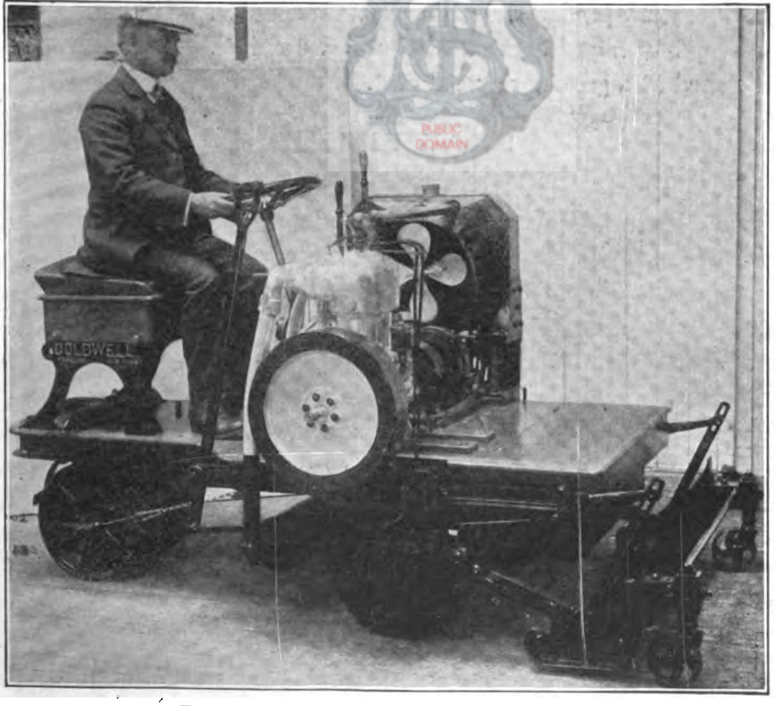


Fig. 318. Coldwell Gasoline-Driven Lawn Mower

any dirt falling into the track is forced out through these openings by the teeth of the track sprocket. As each track may be driven separately through its friction clutch, the tractor can turn in practically its own length by driving one of the tracks and letting the other remain idle, thus causing the machine to revolve almost as if it were on a pivot. Fig. 317 illustrates one of these tractors hauling a disk harrow and a leveling drag.

Coldwell. The Coldwell gasoline-driven lawn mower, Fig. 318, is a type that does not fall into any of the foregoing classes. Its motive power consists of a two-cylinder, four-cycle, vertical motor, placed transversely on a platform. The drive is through the medium of a planetary gear and a chain. The same makers also build lawn mowers with one- and two-cylinder, two-cycle motors.

Generally speaking, the types of vehicles already described suffice to complete the range of those ordinarily employed for agricultural and similar service, and from the accompanying illustrations one may gain an idea not only of the varied character of their usefulness in such operations as plowing, threshing, road-building, and haulage, but likewise the effective manner in which the work is performed at a greatly reduced cost.

STEAM VEHICLES

It will hardly be necessary to mention the fact that the commercial steam vehicle has not been developed to any great extent in this country and is far from being a factor of importance in this field, as this is self-evident from the types of trucks in use. It might be inferred from this that steam had not been found particularly available for commercial use, but quite the contrary is the case, as in England it has doubtless reached about as high a degree of development as this form of power is capable on a road vehicle, while about as much attention has been devoted to it in France as here. As a matter of fact, the steam commercial vehicle was at first developed in Great Britain at the expense of the gasoline type.

White. While numerous attempts have been made in this country to develop steam vehicles, they have met with very limited success, particularly in the commercial field. The makers of the White built a large number of pleasure vehicles for several years and a number of these chassis were employed for commercial service without other alteration than that of fitting special bodies. These cars are still built for export, many of them being sold in Great Britain and in the British Colonies. The power plant of the White steam car consists essentially of a steam generator, a burner, and an engine, together with the necessary devices for supplying water to the generator and fuel to the burner in proper amounts.

The White boiler is a *flash generator* with water at the top and the steam at the bottom, while the relative quantities of the two which happen to be present are of no moment, the generator containing but very little of either at a given time. In fact, the steam is generated instantaneously, and only as fast as it is needed, due to the continuous tubular construction of the generator, which is practically one coil, having but twelve joints, as compared with the many hundred in the usual fire- or water-tube boiler. The White generator consists of nine coils of steel tubing of $\frac{1}{2}$-inch internal diameter, one above the other and connected in series, so that, if straightened out, the entire construction would represent only a single piece of tubing. The water or steam, in order to pass from an upper coil to the one next below, must be forced up to a level above the top coil and then down again, preventing the water from descending by gravity and making the circulation depend entirely upon the pumps. In operation, water is pumped into the upper coil, and steam issues from the lowest coil. The precise point in its travel at which the water "flashes" into steam has never been precisely determined. From its action, this type of boiler is known as a *flash generator*, the small quantity of water and steam it contains at any moment being evident from the fact that its volumetric capacity is less than $\frac{1}{3}$ of a cubic foot; but the process of making steam is so rapid that it is always available in the quantity the running condition of the car may call for, this being governed by an automatic thermostat.

Beneath the generator is located the burner, to which the fuel, consisting of either gasoline or kerosene, is fed under moderate pressure, maintained by an air pump attached to and driven from the engine. The fuel first passes through a vaporizer and then, in the form of gas, enters the burner, where it mixes freely with air and burns with a blue flame, as in the Bunsen burner. The products of combustion pass upward through the coiled tubing of the generator and are then conducted downward through an annular flue surrounding the generator and are led to the rear of the car, where their escape is not noticeable. To start the burner, a pilot light is employed, the small flame of which is kept burning constantly while the car is in use. It serves the double purpose of keeping the vaporizer at the required temperature, and of lighting the burner whenever fuel is supplied to the latter. When kerosene is employed as fuel, it is necessary to use gasoline for the pilot light, but the quantity

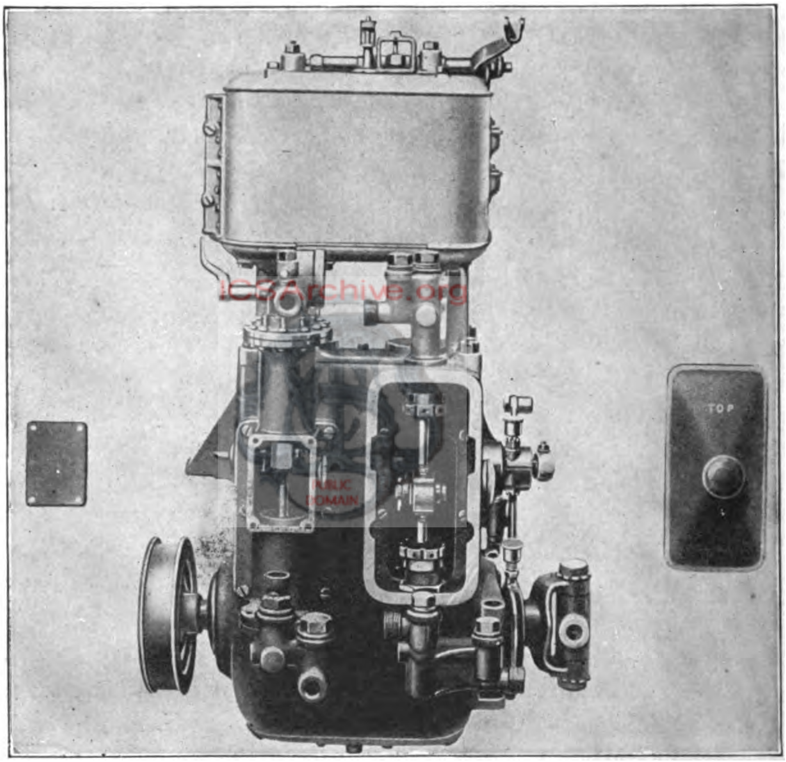


Fig. 319. White Steam Engine—Left Side—with Pump Covers Removed

required is negligible. The vaporizer is a steel forging with a number of passages bored through it, and by its heat converts the fuel from a liquid to a gas.

The engine is a two-cylinder, vertical, compound, condensing type designed to work at about 600 pounds pressure to the square inch. By means of a three-way throttle valve, it may be run as a two-cylinder simple high-pressure engine when extra power is required. The valves are driven directly from the connecting rods by what is known as the "Joy" type of valve gear, the valves themselves being of the piston type. Steam is admitted through the center of the valve and exhausts at its ends; as the pressure is the same on all sides, a negligible amount of power is required to operate the valve. The crankcase is made in one piece, access to the moving parts of the engine being had by large handholes, normally covered with light plates. The side plates are shown in Fig. 319, there being a third large plate on the bottom of the crankcase. The engine is supported on two cross members riveted to the main frame and is so hung that the driving shaft is perfectly horizontal. The drive is direct from the engine through the long driving shaft to the rear axle.

Stanley. This is another American steam car which has been built for more than a decade and marketed chiefly in its home territory, New England, on a more or less limited scale. In recent years, it has also been supplied for commercial service as a delivery wagon by substituting a body of that type, although, like the White, it has been sold more for pleasure use. The boiler is of the fire-tube type, employing copper tubes, and is placed forward under a hood, while the two-cylinder engine is mounted horizontally below the center of the body and drives to the rear axle through a single roller chain running in a housing.

British Types. Great Britain is really the home of the steam commercial car and it has there found its greatest development. Several large makers build steam cars of from three to six tons' capacity, most of them designed to haul trailers, increasing the useful load to eight or ten tons. British conservatism is usually cited as being chiefly responsible for the continued adherence to the steamer, despite the successful development of the gasoline truck. This is true to a certain extent; but it must be borne in mind that the conditions of operation are totally different. In the first place, a large body of trained men skilled in the handling of such vehicles has grown up in England and the operating troubles usually present where the car is intrusted to an inexperienced hand, as in this country, are lacking. Volatile fuels, such as gasoline (petrol), are very much higher in price, while the slow speed of the heavy steamers permits the use of steel tires, both of which factors make the use of these cars very much more economical. Distances are also short.

With the exception of the latter item, similar conditions obtain in the British Colonies, where such vehicles have found a large market. Gasoline is either almost prohibitive in price or not obtainable at all, so that ability to utilize low-grade fuels is imperative. From time to time, a few of these British steamers have been imported into this country, but with rare exceptions they have not met with any success. Instances in which heavy loads can be carried short distances are not frequent, while in some States the drivers must be licensed steam engineers, thus placing them on a par with railway locomotive drivers and making the cost of labor prohibitive.

Sheppee Steam Wagon. As will be noted by Fig. 320, which shows a 3-ton truck of this make, this is really a close approach to

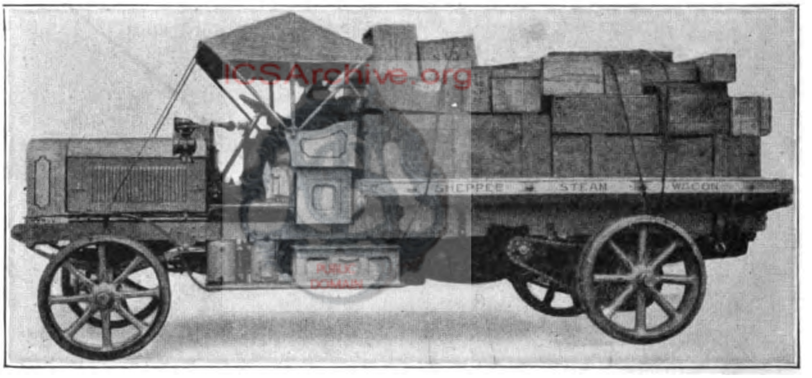


Fig. 320. Sheppee High-Speed Steam Truck

gasoline-truck design in everything except the motive power. Unlike the majority of British steam lorries, it is capable of speeds up to twenty miles an hour, and is, therefore, what may be termed a high-speed type, as most of the others are not capable of exceeding eight miles an hour, and the majority are much slower. Its design is along similar lines to the White, the boiler being a flash generator capable of producing superheated steam up to pressures of 1000 pounds per square inch at temperatures up to 1000 degrees F. The tubes are of solid-drawn seamless steel, the lower ones being wire-wound to give them greater strength. This is also said to prevent scaling and adds greatly to the life of the tube. Fig. 321 illustrates one of the wire-wound sections at the left, a plain tube section at the right, and a wire-wound steam drum above. As this type of generator only produces the steam as required, it is not a boiler in any sense of the term, and consequently is not subject to explosion. Accidental rupture of a tube simply permits the steam to escape without doing any damage, the generator being built in easily replaceable sections which permit of easy repairs.

Kerosene is the fuel employed, and is utilized in a patent form of burner. The combustion is smokeless and no chimney is necessary, nor is an air blast required to provide the draft. The boiler is fed by two independent pumps, one of which is attached to and

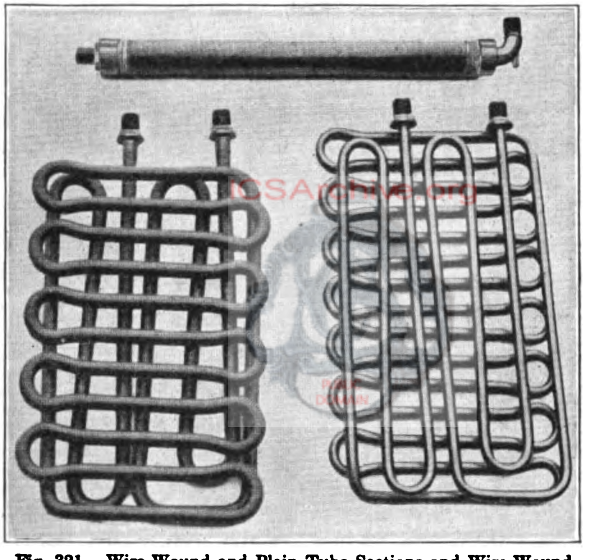


Fig. 321. Wire-Wound and Plain Tube Sections and Wire-Wound Steam Drum of Sheppee Flash Generator

driven through gears by the engine, while the other is a steam pump with mushroom valves, mounted at one side of the chassis in an accessible location and controlled by a throttle valve from the driver's seat. This second pump is employed particularly for hill climbing when the engine speed is low, and, as the amount of power produced by the generator depends upon the quantity of water fed to it, this provides an ample reserve.

The engine is placed horizontally under the center of the body and drives through a heavy silent type of chain to a conventional countershaft equipped with a differential, from which the final drive is by means of the usual side chains.

Foden Steam Wagon. This is representative of the type of steam wagon developed at an early date in Great Britain, large numbers of which are in use for heavy haulage. To the American eye it bears a close resemblance to the familiar traction engine given an increased wheelbase and fitted with a body, Fig. 322. The boiler is of the locomotive type and operates at 200 pounds pressure. As in traction-engine practice in this country, the engine is mounted directly on it. The total heating surface of the tubes and firebox is 70 square feet, and the latter is designed for the use of coke, coal, or wood fuel. The bunker holds sufficient fuel for a 40-mile run, while

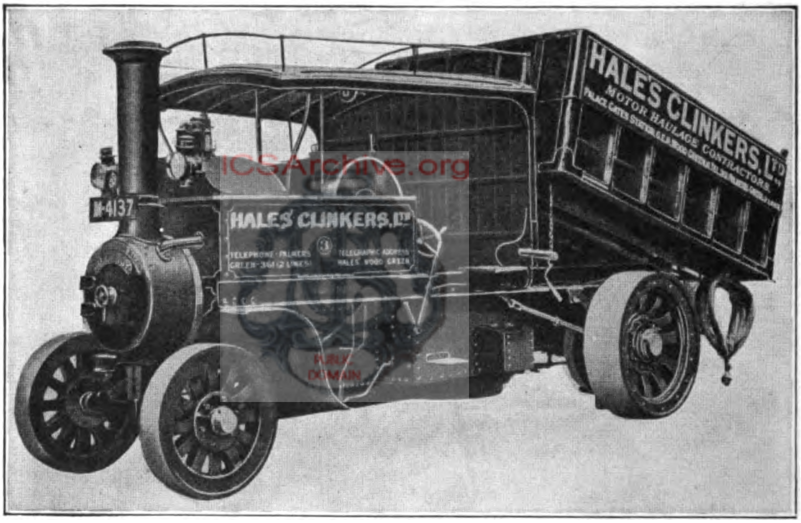


Fig. 322. Seven-Ton Foden Steam Wagon with Tipping Body

the 150-gallon water tank suffices for 18 to 20 miles, both a pump and an injector being fitted for feeding the boiler.

In contrast with traction-engine design, however, the engine is of the compound type, having 4- and $6\frac{3}{4}$-inch cylinders by 7-inch stroke. It is non-condensing, and is provided with means for "simpling", i.e., running both cylinders as simple high-pressure units. This increases the power for ascending grades, but likewise increases the steam and consequently the fuel consumption, so that it is only intended for emergencies. The engine drives through heavy spur gears to a fixed studshaft, giving one speed reduction, and from the latter by a $2\frac{1}{2}$-inch roller chain to the rear axle. A large band brake is placed on the axle and a second one of the same type on the flywheel of the engine. The gears in question provide two speeds, one of 3 miles an hour for the low and the other of 6 miles an hour. The vehicle itself has a capacity of 7 tons and can haul one trailer with a capacity of 3 tons additional.

Two of the Foden steam wagons with trailers have been employed by a New York company for the past few years, and a brief resumé of their cost of operation indicates why heavy steam vehicles of this type cannot compete with gasoline trucks under American conditions. Although the New York motor-vehicle law exempts commercial-vehicle drivers from the steam-boiler-law requirements that all boilers developing more than 10 pounds steam pressure, or more than 10 horsepower, must be attended by a licensed engineer and be under police supervision, the Terminal Transport Company, which owns these machines, evidently regards it as good policy to employ skilled drivers. They receive \$33 per week, and their helpers \$15 per week. Anthracite coal of high grade is burned, to comply with the legal requirements against the production of smoke, thus doubling the expense for fuel as compared with operation abroad, where low-grade bituminous coal is used. Only a cheap grade of lubricating oil is necessary, and as the four-foot driving wheels, as well as the smaller front wheels, are shod with steel tires, the expense from that source is reduced to a minimum. On a daily average of 40 miles, this gives a ton-mile cost of 10.5 cents, the daily cost of operation being \$18. To facilitate unloading, the machine is fitted with a tipping body elevated by a worm gear driven by a belt from the engine, and only 5 minutes are required to raise it to the 30-degree angle necessary to dump the load.

Yorkshire Steam Wagon. The view of the chassis of a Yorkshire 6-ton steam wagon, Fig. 323, makes most of the details of its construction apparent at a glance. The boiler, of the fire-tube type, is placed transversely on the forward end of the chassis, and is fired with coke, the firebox door opening at about the level of the footboards. A 4½- by 7½- by 7½-inch-stroke vertical compound engine is mounted directly back of the driver's seat and drives through a two-speed gear and roller chain to a differential on the rear axle. Two sizes are built, a 3-ton and a 6-ton type, and with steel tires the lighter machine has speeds of 4 and 8 miles an hour, while the heavier one runs at 3 and 6 miles per hour. If fitted with rubber tires, the maximum speeds are increased to 12 and 8 miles an hour,

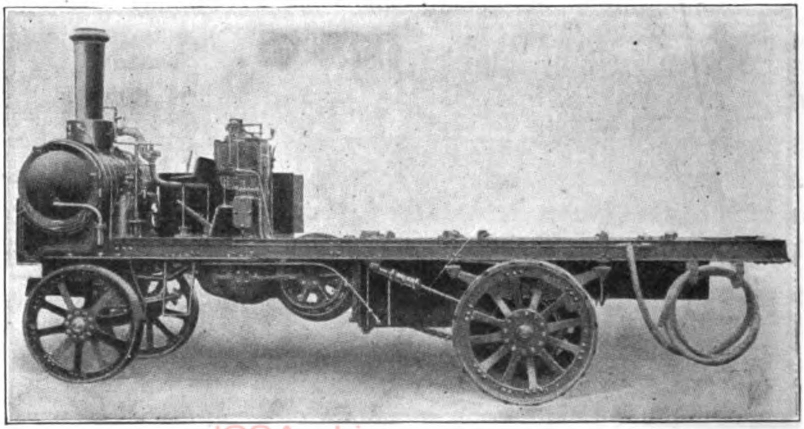


Fig. 323. Chassis of Yorkshire 6-Ton Steam Truck

respectively. One of the features of this machine is the arrangement of exhaust steam jets led into the return tubes of the boiler

Fig. 324. Leyland 6-Ton Steam "Lorry"

instead of the ordinary blast for creating a draft. This also superheats the exhaust steam and renders it practically invisible.

Leyland Steam Wagon. This also is a coke burner, and, as will be noted in the illustration, Fig. 324, it differs only in details of design from the Yorkshire. This view also shows the type of firebox employed on both of these vehicles. It is carried directly below the frame of the machine and has a small door opening forward to regulate the draft, this being controlled from the driver's seat, while the fuel is fed from above. The engine is a horizontal compound type, and is built integral with the two-speed gear and countershaft, from which the final drive to the rear wheels is by means of side chains.

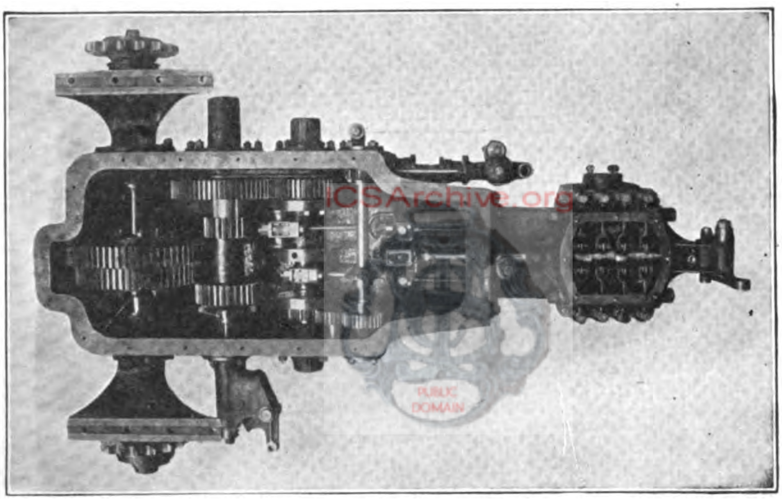


Fig. 325. Leyland Steam Engine and Transmission Unit

As will be noted, the valves are of the lifting type and are actuated by a single camshaft and short rocker arms fitted with roller ends, Fig. 325.

Clarkson Automatic. It will be evident that one of the chief difficulties in the use of solid fuel is the maintenance of a steady steam pressure, as well as the more or less frequent attention needed by the fire. This has been overcome in the National coke-fired steam wagon designed by Thomas W. Clarkson, and as this vehicle not only has numerous ingenious features, but is also employed on one of London's bus lines, a more detailed description will be of interest.

The boiler is a combination of a water-tube steam generator, feed-water heater, and steam superheater all in one, and is built integrally with its fuel bunker when intended for coke, as it is also

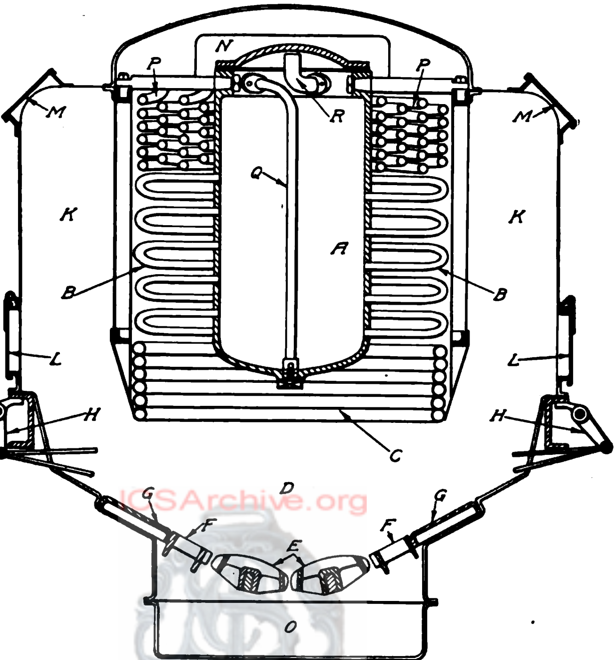


Fig. 326. Details of Steam Generator, Clarkson (National) Automatic Coke-Fired Steam Truck

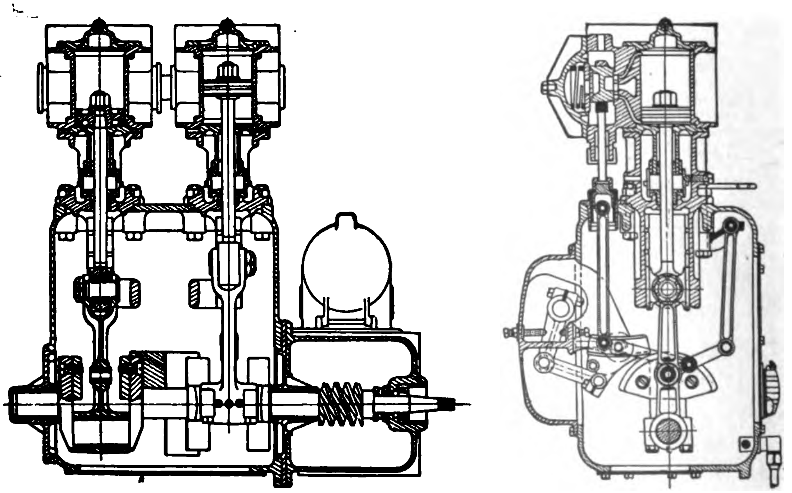


Fig. 327. Sectional Views of Compound Engine, Clarkson (National) Automatic Coke-Fired Steam Truck

designed to be used with liquid fuel. Fig. 326, which is a sectional view, shows the details of this unique combination which makes a very compact unit. *A* is the boiler drum and *B* the U-shaped steam-generating tubes, which are expanded into the drum. *P* is the feed-water heater through which the water enters the boiler, while *C* represents the tubing of the superheater, from which the steam is delivered to the engine at a working pressure of 300 pounds. This unit is concentrically mounted in a circular housing *K*, forming the coke bunker, which completely surrounds the boiler. *D* is the combustion chamber. The heating surface of the generator is 51 square feet and is designed to operate on either up or down draft, no chimney being necessary in the latter case. The filling of the bunker *K* is accomplished through the charging doors *M M*, the doors *L L* simply being for purposes of inspection. The coke is automatically fed to the fire by the feeders *H*, which are driven from the engine, though they may

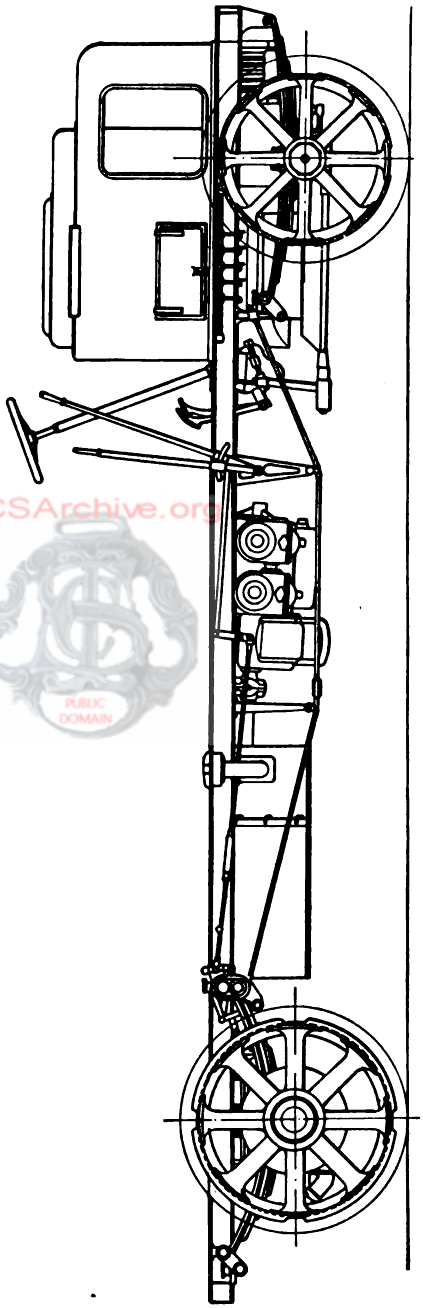


Fig. 328. Chassis of National Coke-Fired Steam Truck

also be operated by hand. Ashes are discharged into the pan *O*, by the rocking grate bars *E*, *F* representing fixed grate bars, and *G* renewable dead plates.

The engine is a compound horizontal type, as shown by the section, Fig. 327, and is mounted transversely on the chassis as illustrated by the view of the latter, Fig. 328. It is a high-speed unit, the bore and stroke being but 4 inches, and develops 32 horsepower. The valve gear is of the Joy type, designed to give a cut-off of about three-eighths of the stroke, two notches being provided on the reversing lever for controlling the valve travel to give increased economy. Oil and water pumps are placed just to the rear of the driver's seat. The power is transmitted through a long propeller shaft fitted with universal and sliding joints and driving through a worm gear of the *overhead* type at the rear axle.

Owing to the special type of steam generator employed, the vehicle is very light when compared with those equipped with fire-tube boilers, and it is capable of traveling at the same speeds and over the same daily mileage as gasoline trucks of the same capacity, i.e., 3 tons. One charge of coke and water is good for 50 to 60 miles, and the driver is relieved of the necessity of giving attention to the fire, except to replenish the fuel and water at stated intervals.

FUELS AND FUEL VAPORIZERS

CHARACTERISTICS OF FUELS

Gasoline. So long as gasoline represents not alone the most efficient fuel for use in motors of the present type, but likewise the most convenient, it will doubtless continue to be generally employed for pleasure-car use, regardless of its increasing cost. This effectively answers the question as to why kerosene is not used for pleasure-car propulsion. It is quite true that kerosene is cheaper, and its value as a fuel for the internal-combustion motor is slightly greater than that of gasoline, but to realize its greater value it requires a motor designed to give a heavier initial compression. Furthermore, it is not as convenient as gasoline, for pre-heating is required to start the motor from cold, because of the higher specific gravity of kerosene,

*Gasoline ranges from .62 to .67 sp.gr. or 95 to 80 degrees Baumé, while kerosene is approximately .80 to 82 sp.gr. or 46 degrees Baumé.

which makes it less volatile, causing it to leave unsightly grease stains on anything with which it comes in contact.

Similar conditions naturally do not obtain in the commercial field, where the demand is for the most efficient and economical fuel. In view of the enormous increase in the demand for gasoline, coupled with the fact that the crude petroleum supply shows a constantly decreasing proportion of the more volatile products—the new wells of the Southwest are said to yield an oil producing not more than five per cent of gasoline in the process of fractional distillation—it is evident that it is only a question of a comparatively few years when gasoline will reach a point where its use for commercial service will not be economically practical. By improving the methods of utilizing the fuel in the internal-combustion motor it will become possible to use petroleum of lower and lower grades, the Diesel motor now running directly on crude petroleum with an efficiency far in advance of the most economical steam plants as well as of most other forms of internal-combustion engine. But to accomplish this an extremely high compression is necessary—500 pounds to the square inch—and the weight involved in a construction required to stand such a pressure naturally makes the use of this type of motor out of the question on a vehicle. Instead of being employed in a carbureter in the manner usually followed on the automobile, air alone is compressed to this high pressure, and the fuel is then injected in the form of a spray directly into the combustion chamber, at or slightly before the beginning of the power stroke. The heat generated by the extremely high compression automatically ignites the charge. While it does not appear probable that the employment of pressures sufficiently high to accomplish this will become possible on the commercial vehicle in the near future, the method of injecting the fuel directly into the cylinder, instead of first carbureting air as is now done, will doubtless have an important bearing on the solution of the fuel problem.

Alcohol. Though volumes have been written during the past few years on the subject of alcohol as the coming fuel, it is the prevailing impression that, notwithstanding favorable legislation, which has made the employment of tax-free denatured alcohol possible, production has not reached a point where its employment on a general scale is commercially practical and few attempts have been made to use it in actual service. The fact that gasoline can still be produced at a price which makes it impossible for alcohol to compete with it has tended to delay the distillation of the latter on a large scale for fuel purposes, besides retarding the manufacture of engines specially adapted to burn it. When employed in an engine designed to run on gasoline, alcohol is neither commercially nor practically efficient, owing to its greater cost and the greater consumption per horsepower, as well as the lower output of the same size motor, due to the lower compression, but that it can be made so under proper conditions of operation is shown.

At the present prevailing prices for denatured alcohol, the cost of running a truck with it is estimated to be approximately $1.25 more per day than with gasoline. Furthermore there is, at present, no stability to the alcohol market and prices may unexpectedly rise to a prohibitive figure. This naturally deters purchasers from investing in trucks equipped with alcohol motors, as the latter cannot be run on gasoline owing to the higher initial compression employed, which would cause pre-ignition.

Two years ago, the Department of Agriculture undertook an exhaustive investigation of the subject, and as the result of experiments made here and abroad, came to the following conclusions:

Alcohol contains 0.6 of the heating value of gasoline, by weight, and, in the department's experiments, a small, single-cylinder engine —designed to run on gasoline—required 1.8 times as much alcohol as gasoline per horsepower hour. This corresponds very closely to the relative heating value of the fuels, indicating practically the same thermal efficiency with the two when vaporization is complete.

By proper manipulation, any engine on the American market today, designed to run on gasoline or kerosene, can be operated on alcohol without any structural change whatever. In some cases, however, carbureters designed for gasoline cannot properly vaporize all the alcohol supplied, and in such cases the excess of alcohol consumed over gasoline is greater. But the absolute excess of alcohol consumed over gasoline will be reduced by such changes in the design of the engine as tend to increase its thermal efficiency.

By altering the design of the carbureter and increasing the initial compression materially, any engine built to run on gasoline will show an increased thermal efficiency, and will then consume less alcohol per horsepower hour in proportion to this increase. An engine designed for gasoline or kerosene will, without any material alterations being necessary to adapt it to alcohol, show slightly more power (approximately 10 per cent) with alcohol than with the fuels for which it was designed, but this increase is at the expense of a greater consumption of fuel. By making alterations designed to adapt the engine to the new fuel, this excess can be increased to fully 20 per cent. Different designs of gasoline and kerosene engines are not equally well adapted for burning alcohol, though all will do so with a fair degree of success.

The storage of alcohol and its use in the motor is attended with much less danger than that of gasoline, and the exhaust from the alcohol motor is not apt to be quite so offensive as that from a gasoline motor, though an excess of lubricant and imperfect combustion will create an odor when the engine is not properly handled. This is now an important factor in city traffic, as pointed out in connection with taxicab operation, and is daily becoming more so as the number of vehicles increases.

No more skill is required to operate an alcohol motor than one designed to run on gasoline, and the combustion chamber of the former does not show the same tendency to soot up, nor does it, with proper operation, show any effects of corrosion. By reason of greater cleanliness in handling the fuel, increased safety of storage, and less offensiveness in the exhaust, alcohol engines will sooner or later begin to displace the gasoline motor, particularly when the production of alcohol reaches a scale where its use will be on practically the same economic level. It has been thought that in this field it would be impossible to conveniently increase the compression of the motor because of starting difficulties, but as the compression release employed for starting on many gasoline motors is equally applicable to the alcohol motor, this should not prove a deterrent.

Distillate. This is the generic term applied to hydrocarbons of several different specific gravities ranging between gasoline and kerosene, and known more particularly by that name in the Far West, where it is refined on a large scale from the crude oils coming from the Texas and California fields. The distillate most successfully employed for internal-combustion engines is between 49 and 50 degrees specific gravity Baumé, having a flash test varying from 130 to 140 degrees, and a cold test of approximately zero. It has the characteristic odor of kerosene, which it closely resembles, but is, of course, more volatile. For its efficient utilization both the carbureter and the motor should have several of the characteristics necessary to the most economic operation with kerosene. Quite a number of trucks on the Pacific Coast have been fitted for its use, which will doubtless increase, owing to the great economy involved, distillate selling at 8 to 10 cents a gallon, as compared with 25 to 30 cents for gasoline in settled districts and up to 50 cents in the mining sections.

Distillate-burning carbureters differ but little in construction from those designed for gasoline, the chief feature necessary being some form of thermostatic regulation of the supply of hot and cold air to control the proper vaporization of the fuel. Their adjustment is also somewhat finer and requires more care to secure efficient combustion. In most of the distillate carbureters used on trucks on the Coast, automatic regulation of the hot- and cold-air intakes is effected through a thermostat actuated by the variations in temperature of the carbureter, and operating to open or close a modified type of butterfly valve in the form of "shutters". With the opening of the throttle, the thermostatic regulator will permit more cold and hot air to enter the carbureter, balancing the quantity of each to maintain a uniform temperature for which it is set. Reducing the fuel supply to the engine causes the regulator to decrease the air in proportion. A spraying screen in the carbureter on which the liquid impinges separates the distillate into very fine particles to accelerate its vaporization. This thermostatic regulation keeps the temperature of the gas in the manifold down to 150 to 175 degrees F. and reduces the temperature of the explosion somewhat, so that motors operating on distillate are not found to run as hot as with gasoline.

To utilize this fuel to the best advantage, the motor should be of the slow-speed, high-compression type, as with kerosene. At present, of course, it is being employed in engines designed for gasoline and fitted with the special form of carbureter. While the power output, as shown by a dynamometer, is less, the loss is insignificant compared with the operating economy. There is no apparent difference in power, and users of trucks state that the same mileage is obtained with distillate as with gasoline, although some trucks will not operate on it successfully, which is doubtless due to their being light machines with high-speed, low-compression motors. In the mining districts of Nevada, Montana, and New Mexico, where gasoline costs 50 to 60 cents a gallon and is not always obtainable, the use of distillate is said to effect a reduction of from $10.50 to $5.00 per ton on long hauls. Gasoline must be used for starting, as with kerosene, but as soon as the motor is warmed up, there is no apparent difference in its operation.

Benzol. In Great Britain and on the Continent, gasoline costs all the way from 50 to 100 per cent more than here, and constant efforts are naturally being made to procure a cheaper fuel. Benzol is a by-product of the manufacture of illuminating gas from coal, and has been used to a considerable extent in Great Britain, Germany, and France. In fact, one of the requirements of subsidized machines in France is that they shall be capable of utilizing gasoline, alcohol, or benzol as fuel. With the present limited supply, its cost is rather high, although not so high as that of gasoline. To offset this its thermal value is somewhat higher even than kerosene, a pound of benzol giving some 23,000 British thermal units as compared with approximately 20,500 for kerosene. It has been found that a certain proportion of benzol added to kerosene tends to correct some of the undesirable characteristics of both. For obvious reasons, its use as a fuel has never been attempted in this country.

Kerosene. With the constantly increasing demand for gasoline and with little prospect of important new sources of supply being found, it is evident that a cheaper fuel is essential for commercial vehicles to insure their economical operation. As the price of gasoline advances that of kerosene drops, so that within the last few years their relative values have been completely reversed. Twenty years ago, gasoline was a by-product, and was burned under the boilers in refineries for lack of demand. In this country, at least, kerosene is assuming the character of a by-product, with gasoline and lubricating oils and their derivatives as the distillates of greatest value. Kerosene is heavier than gasoline, comparatively non-volatile, and has a higher viscosity coefficient. Its specific heat is little, if any, higher than that of gasoline, but its latent heat of vaporization is approximately 2.5 times that of gasoline, and is about 680

B.t.u. per pound (British thermal units). Its composition as to the range and nature of substances comprising the mixture is more diverse than that of gasoline and, as received from the producer, carries a greater quantity of and more widely assorted foreign matter in suspension.

Starting Difficulties. The matter of the relative viscosities of the two fuels has an important bearing on the design of a carbureter for handling kerosene, owing to the great decrease of viscosity of kerosene with increased temperatures as compared with gasoline. According to Sorel, a French authority on carburetion, kerosene of .817 specific gravity will be discharged from a small-bore passage at twice the rate at 90 degrees F. as at 40, while at 140 degrees F. the discharge will be 3.33 times as great as at 40 degrees F., the pressure remaining the same. In the case of .755 gasoline, if the discharge at 40 is taken as unity, that at 90 degrees is 1.30, and at 140 degrees 1.92 with the same head and the same orifice as kerosene.

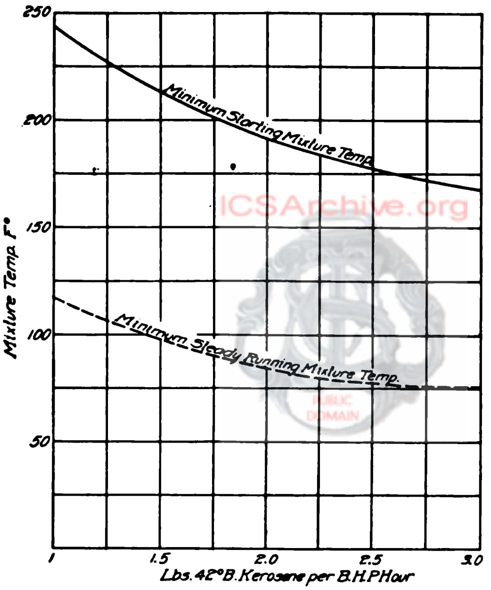


Fig. 329. Curves Showing Kerosene Mixture Temperatures Necessary for Starting Cold and for Minimum Steady Running

In other words, the rate of increase of the kerosene as compared with the gasoline discharge over this temperature range is 1.74.

Even with the extensive heating now practiced with gasoline carbureters, a temperature of 100° F. is seldom exceeded. In kerosene devices of conventional type, the temperatures will often be three times as great. This explains in part the difficulty experienced in securing compensation or proper automatic control of the mixture proportions in the conventional type of carbureter to which heat is applied to adapt it to the use of kerosene. The relative specific heats of the two fuels have only an indirect bearing on the matter of carburetion, as there is scarcely more than .04 B.t.u. per pound difference. But since the boiling or vaporizing temperatures of kerosene are consistently from 2 to 2.5 times higher than for gasoline, it follows that 2 to 2.5 times the heat input is required to bring kerosene to the temperature where vaporization begins.

The relative non-volatility of kerosene is the property that has proved to be the great stumbling block in the development of a commercial kerosene carbureter. It is a practical impossibility to start a cold motor on kerosene, with a cold carbureting device and the ordinary system of intake piping for the distribution of the mixture. With even the lowest grades of gasoline, starting can be effected without great difficulty even under the most adverse temperature conditions experienced in this latitude. There are certain of the components of 58-degree Baumé gasoline which volatilize below 50 degrees F. Though they are present in small quantity, there is sufficient to start by directly priming the cylinders or strangling the carbureter, and the heating of the motor does the rest. In the case of kerosene, however, the first components to vaporize do not do so below 135 to 140 degrees F. Hence the futility of attempting to start with everything cold. The curves, Fig. 329, show the minimum starting and running temperatures necessary with kerosene.

KEROSENE CARBURETERS

As a carbureting system of conventional type cannot be made to operate flexibly and economically without an input of heat to the mixture sufficient, or nearly sufficient, to completely vaporize the fuel, the modification of design as compared with that of the gasoline carbureter is largely one for providing the necessary rise in temperature. The kerosene carbureter is primarily a vaporizer, the heat of the exhaust being utilized to convert the kerosene atomized by the nozzle or spraying device into a true vapor, or gas. It is in the methods adopted to effect this that the kerosene-carbureter design chiefly differs, as will be clear by referring to a few of them.

Holley. The Holley kerosene carbureter is shown in Fig. 330. Kerosene is fed at *M*, passing through the screen *N*, and then through the gasoline inlet *O* (gasoline must be used for starting), which is operated by a conventional type of float mechanism, the level being maintained constant, as usual. The action of the mixing chamber is as follows: The exhaust gases from the motor enter at F, pass around the low-speed tube R and the high-speed tube L, and pass out at S. The primary air (main supply) enters at I and is heated by passing around the exhaust tube J. This flows over to the mixing chamber at low speeds through the tube R, supplied by the nozzle Q. As the butterfly valve B (throttle) is opened, fuel is supplied by the nozzle K, as well as from Q. The atomized kerosene, as the speed increases, flows with the mixed air through the corrugated tube L, which is so constructed as to afford the maximum heating surface for its length. At low speed, the auxiliary air valve D is closed over the ports E, but as the suction increases, this valve lifts accordingly and supplies the auxiliary air required.

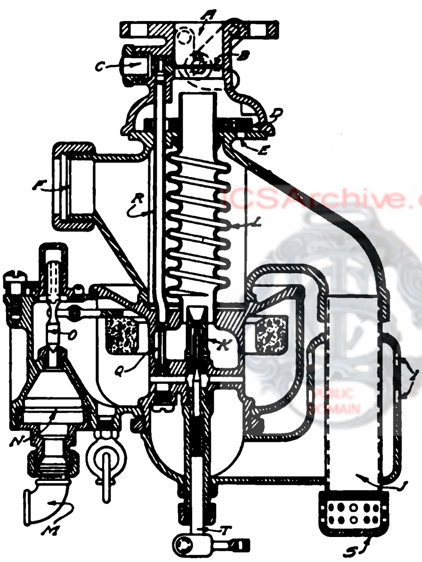


Fig. 330. Sectional View of Holley Kerosene Carbureter

The starting device used in connection with this carbureter is independent of it though operated in conjunction with it. It is practically a floatless gasoline carbureter with a starvation type of atomizing nozzle at one end, i.e., one in which the orifice can be wholly closed by an adjustable needle valve. The gasoline is injected into the manifold at a point near the cylinders and well above the kerosene carbureter, which is always in action. To start, the gasoline carbureter is put in action by a lever on the dash, and the mixture supplied is then about 75 per cent gasoline. As the throttle of the kerosene carbureter is opened, this proportion decreases as the motor speed increases, so that at driving speeds, even when starting away, the mixture is 50 per cent kerosene. As soon as a sufficiently high temperature is reached, the gasoline nozzle is closed by shutting the needle valve from the dash.

Davis Carbureter. The Davis carbureter is one of the oldest European appliances for utilizing kerosene. It is practically a combined gasoline and kerosene carbureter, or carbureter-vaporizer. As shown at the lower left-hand of Fig. 331, two standard float chambers, each with a separate float, needle valve, and control cock, meet at the apex of a Y-connection and deliver through a common orifice to an adjustable nozzle *D*, shown in the section at the right. The upper opening of this passage is controlled by the taper pin *F*, let into the valve *E*, the latter being a poppet valve controlled by a

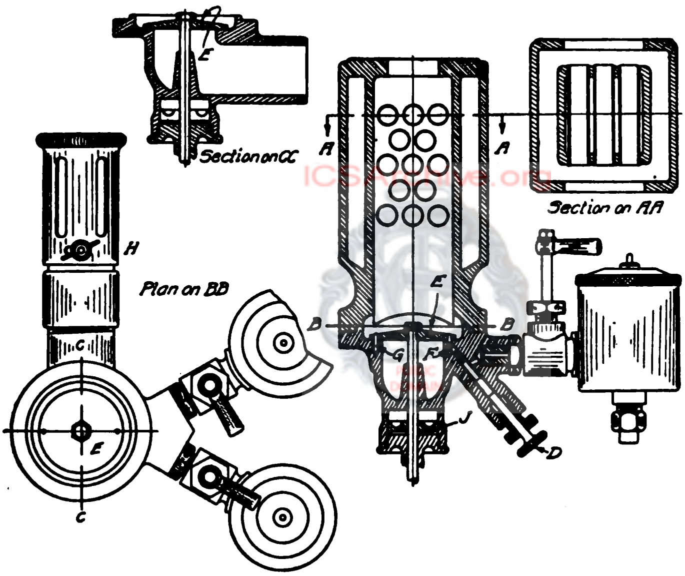
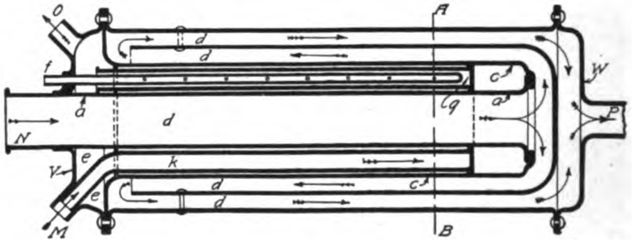


Fig. 331. Sectional and Plan Drawings of the Davis Paraffin (Kerosene) Carbureter

light spring not appearing in the drawing. This spring surrounds the valve spindle and holds the valve on its seat, exactly the same as the motor valve. The parallel pin *G* acts as a guide. Beneath this valve is the air intake, controlled by the semi-rotary regulator *H*, as shown at the left. In the mixing chamber above this valve are a number of copper tubes communicating with the heating jacket surrounding the mixing chamber. This jacket is connected with the exhaust manifold of the motor. Starting is accomplished on gasoline, and, as soon as the vaporizer is sufficiently hot, it is shut off, and the motor then runs on kerosene.

G. C. Vaporizer. This is the invention of a Roumanian engineer and is said to be one of the most successful devices for employing



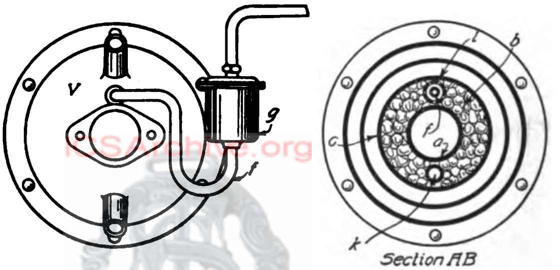


Fig. 332. Sectional Views Showing Internal Details of G. C. Vaporizer

kerosene in use abroad. It is based upon utilizing the entire heating capacity of the muffler or silencer to vaporize the kerosene and

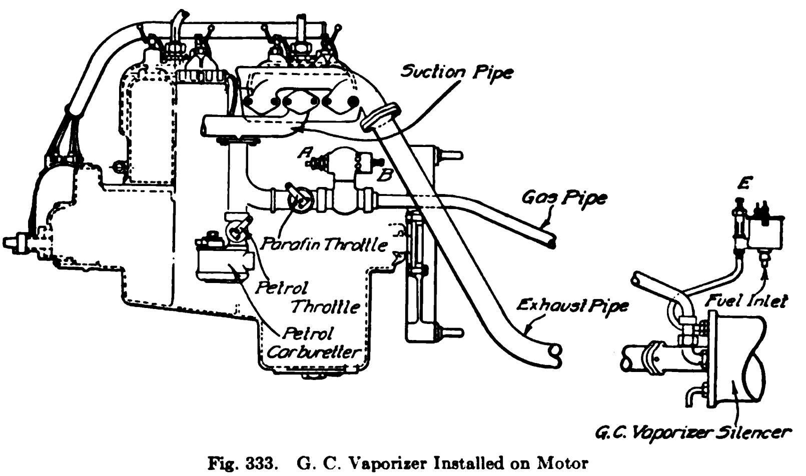


Fig. 333. G. C. Vaporizer Installed on Motor

deliver it as a gas directly into the manifold, an auxiliary air valve of conventional type inserted in the supply line taking care of the extra demand for air. Fig. 332 shows a section of the muffler or "vaporizer-silencer". The exhaust from the motor enters at *N* and follows the direction of the arrows along the passages *d*, emerging at *P*, whence it can be led through another muffler, if necessary. Kerosene flows by gravity from the supply tank to a tube passing along the top of an annulus, or concentric jacket, surrounding the exhaust pipe which constitutes its inner wall. This space, shown at *b* in the section, is filled with iron rods, which, being directly subjected to the heat of the exhaust, soon reach a high temperature. The kerosene enters this chamber at *f* and the tube is extended into the chamber and perforated along its length, so that the kerosene is ejected from a number of small openings on to the red-hot iron and is thus vaporized. At the same time, a pre-determined amount of air is drawn in at the opening *k* and mixes with the gas. The resulting mixture of kerosene gas and air is drawn out of the muffler at the opening *O* at high velocity, its speed being important to keep the mixture as homogeneous as possible. To insure this, the connecting pipe is of small diameter as compared with the usual manifold. The entire vaporizer is heavily lagged with asbestos to retain the heat. Fig. 333 shows the arrangement of the installation. *E* is a conventional float chamber for regulating the supply of kerosene to the vaporizer in accordance with the demands of the motor. *A-B* is the auxiliary air valve inserted in the gas line, and just to the left of it is the throttle for the kerosene (paraffin) mixture. On an extension of the vertical member of the manifold is a standard gasoline (petrol) carbureter for starting, this being cut off by the throttle shown, after the motor is warm enough to run on kerosene. The "suction pipe" is the horizontal member of the intake manifold.

Southey Kerosene Gas-Producer. Vaporizers such as those described transform liquid fuel into gas without fundamentally altering its chemical composition, save for more or less "cracking" of some of the lighter components from chemical combination with the heavier. This means that the resulting gas could be passed through a condenser and emerge practically the same liquid from which it was produced. A gas-producer, on the other hand, takes the liquid and, by the application of heat in the presence of a small amount of air in what is virtually a partial-combustion process, turns out a product that is mainly a fixed gas which has lost all identity with the liquid. In addition to the partial combustion, the process is essentially a simplification of the complex radicals of the liquid. Most producers evolve carbon monoxide (CO) with a small amount of free hydrogen and "unsatisfied" hydrocarbon radicals, which, with the oxygen from the air, constitute the explosive mixture. The final combustion of such a gas is, therefore, the oxidation of CO to CO_2.

Fig. 334 shows the Southey kerosene gas-producer of this type, a British device developed by the makers of the Commer trucks. In appearance it resembles a standard carbureter and is attached to the manifold in the usual manner. The chamber at the lower left-hand is a conventional float-valve arrangement to which fuel is supplied by the pipe shown. A second pipe at the lower right is connected to one of the cylinders from which pressure is taken. This pressure serves to force the kerosene through the usual atomizing jet, the spray impinging against a baffle plate and being mixed with air. It is then fired by means of the spark plug shown extending from the mixing chamber at the left. The electrode of this plug extends into an inverted perforated cone, as shown. As long as the motor is running, there is a ring of blue flame around the upper part of this cone and the mixture of atomized kerosene and air must pass through it. Part of the mixture, of course, serves to feed the flame, the heat of which decomposes the heavier radicals. Instead of the flame being one of complete combustion, however, it is said that the processes are arrested in an incomplete state by the cooling of the gas in the manifold, and also by the absence of sufficient oxygen in the heating chamber. The addition of an auxiliary supply of air completes the mixture.

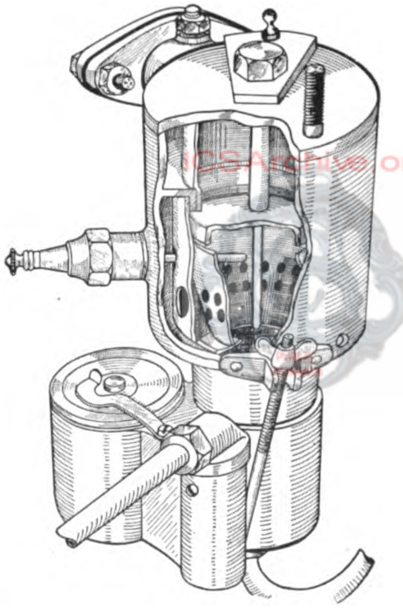


Fig. 334. Southey Kerosene Gas-Producer

Belsize Bi-Fuel Carbureter. As its name indicates, this is practically a double carbureter, adapted to use either fuel. It comprises a pair of single-jet chambers, A and B, Fig. 335, the former being for gasoline and the latter for kerosene, the respective fuel nozzles or jets being A_1 and B_1. Each chamber has a weighted air valve, C and D, respectively, and to each is attached an adjustable and carefully graded needle, E and F, so that any displacement of the valves simultaneously affects the normal position of these needle valves. Each chamber has its own float chamber, as in the Davis, so that the two fuels are kept separate and supplied independently.

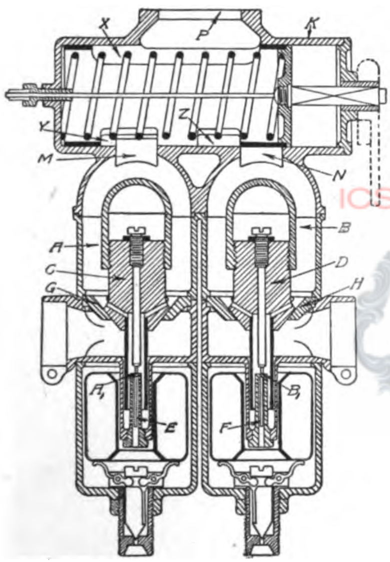


Fig. 335. Belsize Bi-Fuel Carbureter

The registering edge of the air valves is circular and rises to open within an air ring G and H, having conoidal-shaped walls, the curve of which has been carefully worked out for all ranges of fuel and air intake. The fuel nozzles do not discharge directly into the mixing chambers, but are situated within small choke tubes, and the needles are arranged to be adjusted by means of the nuts and fillister-headed screws shown, while the engine is running. Correct adjustment is denoted by the steady running of the motor and its ability to pick up quickly on a sudden opening of the throttle after about 10 minutes' slow running.

The throttle chamber K is a cylinder having rectangular ports M and N communicating with the respective gasoline and kerosene chambers A and B. The throttle valve is a sleeve having a dial—i.e., partly rotating and partly reciprocating—movement against the tension of a spring. There are ports X, Y, and Z in the throttle, of which the member X is large enough not to restrict the mixture outlet to the engine irrespective of the throttle's position. Ports Y and Z are rectangular and register with ports M and N, but not simultaneously. They are so arranged that at one end of the longitudinal movement of the sleeve, only one set of ports are open, the other set being just cut off. Hence, moving the sleeve longitudinally gradually closes one set and simultaneously opens the other set. Thus it is possible to adjust the sleeve in a position to give any desirable ratio of opening of the two sets. On the other hand, rotation of the sleeve simultaneously opens or closes both sets of ports, thus acting synchronously on both mixture chambers. This, of course, constitutes the real or normal throttle movement. The reciprocating movement is for changing over from one fuel to another.

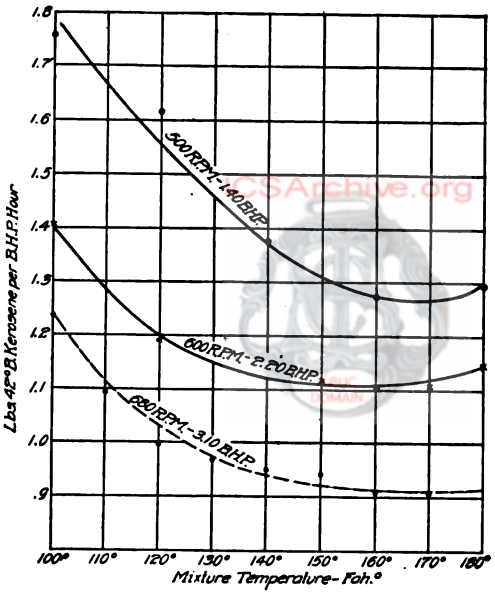


Fig. 336. Curves Showing Influence of Mixture Temperatures on Economy

Economy. Having a slightly greater heating value than gasoline, it will be evident that when properly utilized kerosene is a more economical fuel apart from the great difference in its cost. Economy in its use, however, is largely a function of the amount of heat supplied, as will be noted by the curves, Fig. 336, showing the influence of the temperature of the mixture on the fuel consumption. These curves illustrate very graphically what an influence the heat input, as represented partly by the mixture temperature, has upon the economy of operation. It will be noted that the temperature of most economical operation covers the same range in each case, i.e., 150 to 170 degrees F.

While a great amount of experimenting is being done in this country with a view to the development of an efficient kerosene carbureter, probably the only commercial use to which any heavy fuel carbureter is being put commercially is that of the distillate type used on the Pacific Coast. In Great Britain on the other hand, where fuel costs are so much greater, kerosene carbureters are more or less generally used, and are fitted on trucks exported to the Colonies. In a test run of a Commer truck, fitted with the Southey gas-producer, a consumption of 15 miles per gallon was made with a car weighing, with load, 3672 pounds. This amounts to 50.16 ton-miles per gallon, British standard, or 60.19 ton-miles (short tons) per gallon, United States standard. The Belsize cars are fitted with the bi-fuel carbureter described, while quite a number of the Lacre and Albion cars have also been equipped with kerosene carbureters. The British army has had several Thornycroft trucks which have been operating on kerosene for the past six years or more, while a London trucking concern using about a hundred machines, mostly of this make, have also been employing kerosene with marked economy, the cost of kerosene averaging 14 cents per gallon as compared with 27 cents for gasoline.

OPERATION PROBLEMS

COST

Use of Commercial Vehicles a Business Proposition. While the ability to compete with other forms of transportation was the first determining factor in the history of the development of commercial vehicles, it is needless to add that the factor of greatest importance bearing upon its general adoption is the cost of operation. One of the very first questions put by the intending purchaser is "What is such a vehicle going to cost to maintain it in service?"—and a large amount of engineering talent is now employed in trying to formulate an answer to this question in each individual case. In fact, the analysis of merchandise transportation requirements and the cost of the service as compared with old methods is rapidly developing into an engineering study of no mean proportions.

It will be evident that, under the circumstances, definite figures are wanted by the purchaser, and they can be based only on actual experience. The merchant who contemplates making a substantial investment in commercial vehicles wants to see something more than a mere calculation of what their services will cost—not for a month or two months, but, as closely as can be judged, what it will cost to run and keep them in repair during the first year and each succeeding year of the useful life of the vehicle.

Naturally there are many factors to be taken into consideration in any complete cost-accounting system that is worthy of the name, whether it be for a single delivery wagon or truck, or for a whole delivery system, such as is employed by the large retail dry-goods establishments. Lack of consideration of these numerous factors has led many commercial-vehicle manufacturers into stating half-truths regarding the economic performances of their vehicles in the earlier days, and it is not certain by any means that the practice has entirely disappeared even now. However, the revelation of the whole truth naturally proved a disappointment to the pioneer users of motor vehicles, and the result was a feeling of distrust. It could not have been worse had the manufacturer actually made misstatements, for the user regarded them as such in the light of his experience. To cite instances of what is meant by these half-truthful statements, there may be mentioned the cases of cost summaries which some makers print in their catalogues. Sometimes these extend over a period of three months, and in others six months, and the service records thus established are expected to be regarded as a criterion of what the vehicle is capable of year in and year out. In some cases, nothing for tire replacement is included, owing to the short time the vehicle has been in use, not to mention such additional items as depreciation, interest, insurance, and other overhead charges. Seldom, indeed, is the useful ton-mileage of the car, over the period in question, given, and quite a number of manufacturers, when approached for information on this vitally important subject, confess that they are unable to give it and that they have never attempted to keep a record of the kind.

Some of the factors of importance are speed, reliability, wide radius of travel, and even stylishness—which is considered an asset of the motor delivery wagon—but, after all, cost must be practically the sole governing factor by which the commercial motor vehicle is to be judged. At the outset, it was really the uncertainty—that lack of reliability which made the successful completion of a day's trip an entirely unknown factor—which first militated against the commercial vehicle; but since this has been eliminated by improvement in design, materials, and construction, the cost of operation is really the paramount consideration. It manifestly lies more within the province of an article on cost accounting for commercial-vehicle service, than of one which deals almost entirely with the engineering side of the subject. Consequently, the aim has been to demonstrate rather what the commercial vehicle is capable of—particularly as compared with former methods by horse haulage, figures on the cost of operation being cited more to show the superiority of the power wagon from an economic standpoint as well—than to attempt to set forth exactly what has been or can be done in operating one or more vehicles.

Gasoline. Leaving aside the matters of interest, depreciation, insurance, and repairs, it will be apparent that in the commercial vehicle, fuel, lubricant, and tires are of far more importance than in a pleasure car. One of the small 500-pound delivery wagons will usually travel from 18 miles to 25 miles on a gallon of gasoline, averaging better than 20 miles; a 10-ton truck will average less than 3 miles to the gallon of fuel. Between these two extremes, there is a wide range, a 1500-pound delivery wagon running 10 to 16 miles to the gallon, with an average of about 12 miles, while a 3000-pound machine (the figures refer to load capacity and not to chassis weight) will not do better than 8 to 15 miles per gallon, with an average around 10 miles. A 3-ton truck will range from 4 to 8 miles, the difference in every case naturally depending not only upon whether the vehicle is loaded or not, but also upon the differences in the road surface and the grades of its routes. The 5-ton wagon can travel 3 to 5 miles on a gallon of fuel, its average being about 4½ miles as compared with 6 miles for the 3-ton size. A 14-ton road train may require as much as two gallons of fuel for every mile covered, but will doubtless be found not to greatly exceed a gallon to the mile except where the going is particularly bad.

Lubricating Oil. The consumption of lubricating oil ranges between even wider limits than that of fuel, as will be apparent from the fact that in a commercial-vehicle trial, in which a large number of representative foreign vehicles competed, the ratio between the most economical and the most wasteful was fully five to one. In other words, some cars consumed five times as much lubricating oil per mile as others in the same class. But then certain of the European cars have proved to be highly economical in the use of lubricant and it is doubtful if there would be as wide a range between the same number of American commercial cars, as few of them have approached the degree of economy achieved in this respect by the French designer. Experience has shown that the minimum consumption of oil, which should be of the very best quality for the purpose, is about one gallon for every 14 to 15 gallons of fuel used by the vehicle, while the maximum is approximately one gallon for every six gallons of gasoline. Where much hill-climbing is the rule, more oil would necessarily be used, owing to the motor running for longer periods on the lower gears and under correspondingly heavier loads. These figures are based upon ordinarily competent management of the machine, and while an expert driver, thoroughly conversant with his machine, and supplemented by painstaking garage attendance, might do somewhat better, incompetence in either of these departments can swell these figures so tremendously that there is no means of estimating to what proportions they may attain.

Tires. Next to fuel and oil come tires, and in figuring on this subject an engineer who has had five years' experience in the commercial field in a consulting capacity gives the following: For a 500-pound wagon, $\frac{3}{4}$ cent per mile minimum, $2\frac{1}{2}$ cents maximum, average $1\frac{1}{2}$ cents; 1500-pound class, or regular delivery wagon type, 1 minimum, $3\frac{1}{2}$ maximum, and $2\frac{1}{2}$ cents average per mile; 3000-pound class, $1\frac{1}{2}$, 5, and $3\frac{1}{2}$ cents per mile; 3-ton class, 2, 7, and $4\frac{3}{4}$ cents per mile; 5-ton class, 3, 10, and 6 cents per mile. Against these figures, may be placed those which the builders of the Mack cars give as the result of five years' experience in the running of a large number of their own vehicles: Operating 2-ton truck, 2 cents per mile, the figure in each case being the average; 3-ton truck, $2\frac{1}{2}$ cents per mile; 4-ton truck, 3 cents per mile; and the 5-ton truck, 4 cents per mile, this last falling between the minimum and the average for this class in the foregoing figures. Unfortunately no data is available at the moment on tire costs on electric commercial vehicles, though it may be stated definitely that, owing to the lower average speeds and the greater ease with which the load is started by the electric motor, this type of vehicle shows much greater economy in tires than the gasoline car, though exactly how much is a question that could be answered only by a direct comparison of the figures.

Typical Operation Costs. While it is obviously beyond the scope of the present article to go into this at any length, a few examples of total costs and ton-mile costs throw considerable light on the economy possible with various types of commercial cars. Ton-mile costs naturally afford no criterion on the performance of light delivery wagons, particularly in department-store service in which the cost per package is taken as the basis, the weights being very small in comparison with the distances traveled.

Delivery Wagon, 1500 Pounds' Capacity. The average cost of operation of four 1500-pound gasoline delivery wagons in service of this nature, extending over a year, worked out as follows: Gasoline, \$283.44; lubricating oil, \$49.20; tank recharges (acetylene gas for lighting), \$12; chains, speedometer, tools and other incidentals of equipment requiring repair or replacement, \$33.90; tires, \$374.48; tire and tube repairs (pneumatics), \$91.65; driver's wages, \$700; helper, \$260; total, \$1804.67. The number of packages delivered was 86,432, and an average of 49.5 miles was covered per day. The average number of packages being 282.5 per day, the cost per package, including interest on investment, insurance, and depreciation in addition to the working charges mentioned, worked out at slightly less than 3½ cents.

Heavy-Capacity Vehicle. As an example of what may be accomplished with a heavy-capacity vehicle, the accompanying summary, showing the actual total working costs of a 5-ton truck for one year, will be of interest. The chief variable in this is the cost of fuel, which is given here as 9.5 cents per gallon. However, the total fuel cost is small as compared with such items as labor and tires, so that, except in localities where gasoline is very high, as in the Far West, an increase in this item up to 50 per cent of that given would not affect the result very materially. Under normally favorable conditions, fuel is, in reality, one of the lesser items of maintenance, as it will be noted in the present instance that it is considerably exceeded by every other important essential, save lubricating oil. The figures are as follows:

ACTUAL COST FIGURES OF FIVE-TON PIERCE TRUCK FOR 243 WORKING DAYS

Interest on \$4,800 at 6 per cent	\$ 242.40
General insurance	85.24
Driver's salary	781.70
Helper's salary	605.15
Fixed charges	**\$1,714.49**
Fixed charges per day	**7.05**

Tires at .0611 per mile	$ 451.63
Gasoline at .095 per gallon	169.73
Motor oil at .0725 per pint	17.96
Lubrication allowance at .0013 per mile	9.59
Running repairs	37.97
Mechanical repairs	112.59
Body repairs	52.42
Repainting	64.02
Depreciation at .032 per mile	236.63
Operating expense	$1,152.54
Operating expense for one mile	.1558
Total expenses	$2,867.03
Total expenses per day	11.79
Cost per ton to handle	.545
Cost per ton-mile	.119
Ton-miles operated	24,028.00
Cost per mile	.387

PERFORMANCE ANALYZED

Number actual working days	243.00
Total loads carried in tons	5,257.50
Average tonnage per day	21.63
Average tonnage per load	3.25
Total mileage covered	7,392.50
Highest daily mileage	52.00
Lowest daily average	8.00
Average daily mileage	30.42
Gasoline consumed—gallons	1,789.00
Miles per gallon gasoline	4.13
Motor oil consumed—pints	248.00
Miles per gallon oil	238.60
Total number of stops	4,706.00
Average number of stops daily	19.37
Highest number of stops daily	48.00
Lowest number of stops	2.00

Comparative Costs. *Team vs. 5-Ton Truck.* Volumes could be written on the economy to be attained in motor transportation as compared with horses in various forms of service, but one or two comparisons will suffice to show why the horse is being rapidly superseded. The conditions of operation on which the appended summary is based were as follows: Distance, round trip, 10 miles; dirt roads; material, broken stone hauled from a quarry for road-building operations. The route included one 14-per cent grade, which had to be taken with load. Owing to an unsafe bridge the motor truck had to make a detour of one mile, so that the distance for the animals was only 9 miles. The trucks had a great advantage over the horse-drawn wagons, as they were fitted with dumping bodies, by the aid of which the load of stone could be spread on the road by discharging as the truck moved slowly ahead, this requiring but 10 minutes to a load. The following figures gives an accurate comparison, both of the work done and the cost of the two methods.

FOUR-MULE TEAM HAULING FOUR AND ONE-HALF TONS TWENTY-SEVEN MILES

First Cost

Four mules at $325 each	$1,300.00
Harness	75.00
Wagon	250.00
	$1,625.00

MULES

Interest on one-half investment at 6 per cent	$ 48.75
Insurance on team	32.50
Depreciation 20 per cent	325.00
Fixed charges per year	$406.25
Fixed charges per day	1.85

COSTS PER DAY, ASSUMING 225 WORKING DAYS PER YEAR

Wages per day	$1.84
Feeding at 60 cents per head	2.40
Stable man	.25
Doctor	.20
Shoeing	.30
Repairs	.20
140 days' feeding at 40 cents per head, $224.00	.99
Total daily operating cost	$6.18
Fixed charges per day	1.85
	$8.03

FIVE-TON DUMP TRUCK HAULING FIVE TONS SIXTY MILES

First Cost

Truck	$5,300.00

TRUCK

Interest on half the investment at 6 per cent	$159.00
Insurance on truck, 2½ per cent on 80 per cent of one-half value	53.00
Depreciation on truck (not including tires)	480.00
Fixed charges per year	$692.00
Fixed charges per day	3.07

COST PER DAY, ASSUMING 225 WORKING DAYS PER YEAR

Wages per day	$ 2.50
Maintenance, 4½ cents per mile	2.70
Tires, 6 cents per mile	3.60
Gasoline, 4 cents per mile	2.40
Oil	.60
	$11.80
	3.07
	$14.87

From these figures, it will be seen that the four-mule team did 57.37 ton-miles per day at a cost of 13.9 cents per ton-mile, while the 5-ton truck did 150 ton-miles per day at a cost of 9.9 cents per ton-mile, amounting to a saving of about $6.00 per day.

Important Factors in Motor Truck Work. The advent of the motor truck into the transportation field has led to a more careful investigation of the cost of carrying merchandise and building materials than has been customary in the past, outside of the rail-

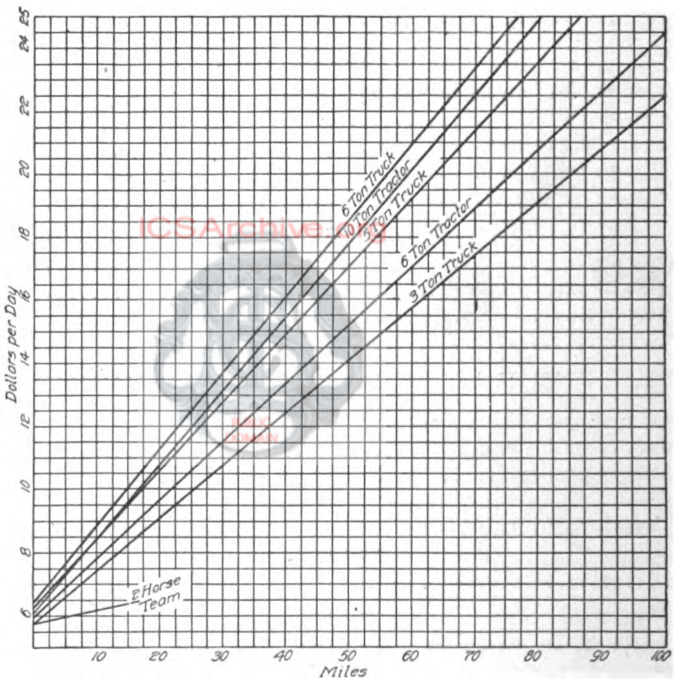


Fig. 337. Comparative Costs of 2-Horse Team and Various Sizes of Motor Units

roads or other long distance carriers. The advantage of the motor truck for much of the delivery and trucking service has been established, and a considerable amount of data is gradually accumulating on the cost of hauling. An examination of a large amount of this data brings out the following facts prominently:

(1) The great advantage of using hauling units of large capacity wherever the nature of the material to be hauled makes a large tonnage practicable.

(2) The very important percentage which fixed charges are of the total cost in the case of the motor truck.

(3) Reduction in cost per ton-mile in proportion to the increase of daily mileage.

(4) Importance of eliminating what may be termed "idle time" in reducing cost per ton-mile.

(5) The large direct operating charge for tires on the motor truck.

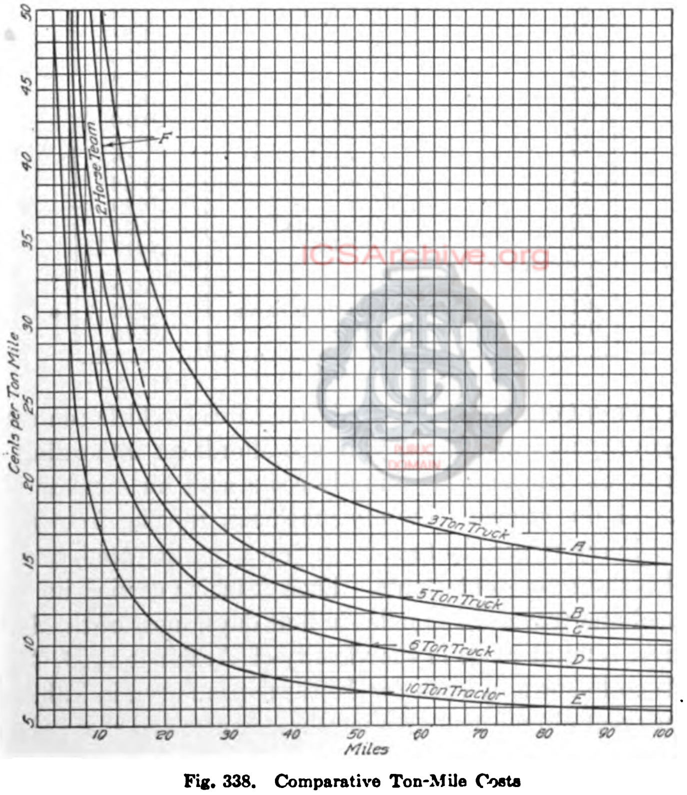


Fig. 338. Comparative Ton-Mile Costs

Fig. 337 shows diagrammatically a comparison of total costs of various sizes of motor trucks and tractors, as well as of a two-horse team, while in Fig. 338, a comparison of haulage costs in cents per ton-mile for various motor vehicles ranging from the 3-ton truck up to the 10-ton tractor are shown. The curves are based upon an extended investigation made by the engineering department of the New England Audit Company.

TABLE VIII

Ton-Mile Cost Tests for Motor Trucks

Number	Name	Ton-Mile Cost
1	Vulcan	.0122
2	Mais	.0220
3	Little Giant	.0277
4	Witt-Will	.0289
5	Wilcox	.0260
8	Rowe	.0262
9	Hupmobile	.0474
10	McIntyre	.0181
11	Autocar	.0183
12	Lauth-Juergens	.0214
13	Atterbury	.0279
14	Atterbury	.0270
15	Atterbury	.0185
16	Atterbury	.0172
17	White	.0238
18	White	.0140
19	International	.0347
20	Atterbury	.0417
Non-contestants		
100	Brown	.0442
101	Four-wheel drive	.0525
102	White	.0276

Results of Government Tests. A commercial-vehicle contest held under government auspices a year ago affords an interesting comparison of the decrease in ton-mile costs with an increase in the capacity of the vehicle. Twenty machines, ranging from a 1500-pound delivery wagon up to a 6-ton truck, participated, and there were also three non-contestants. Each machine carried its normal rated load and traveled 288 miles in four days, most of the distance being over country roads in the vicinity of Washington, D.C. The ton-mile cost shown by each car for the trip is shown in Table VIII.

The great discrepancy between these figures and those of actual service, as shown in some of the previous tables, is accounted for by the fact that in the present instance fixed charges are not taken into consideration.

Electric Trucks. *Electrics vs. Horses.* Generally speaking, the electric vehicle is best adapted to city service where the streets are in fairly good condition, while the gasoline truck shows its best economy with heavy loads and on longer hauls, owing to its greater speed. One or two instances of the cost of electric-vehicle operation will suffice. The naval gun factory at Washington, District of

Columbia, has had several electric vehicles in service for a number of years. They are of 2500-pound and 5-ton capacity. The following figures show the detailed cost per year of operating the 2500-pound vehicles as compared with the number of horses displaced by one of these machines:

2500-POUND ELECTRIC TRUCK

Cost of truck	$2,230.00		
Labor for charging batteries		$ 46.44	
Charging		16.50	
Acid		18.00	
Rubber jars		15.00	
Batteries (partly renewed)		64.98	
Carbon brushes		1.80	
Repairs		99.96	
One operator at $2.48 per day		776.24	
Two laborers at $1.92 per day each		1,201.92	
Totals	$2,230.00	$2,240.84	
Depreciation 10 per cent		223.00	
Interest on investment at 2 per cent		44.60	
Total cost of service			$2,508.44
Total mileage per year	3,366		
Cost per mile	$0.745		
This truck displaced 5 horses and carts, costing as follows:			
Five carts by contract at $1.92 per day		$3,004.80	
Five laborers at $1.92 per day each		3,004.80	
Total			$6,009.60
Net saving of truck over horses per year			$3,501.16

The cost of operating the 5-ton trucks was practically the same as that of the 2500-pound size, except for the difference in tire costs, and the fact that charging the lighter car cost 75 cents for a 40-mile radius, while for the same distance the current cost of the heavier machine was $1.10, the current being figured at 1 cent per kilowatt hour, which is lower than is enjoyed by the majority of the users of electric vehicle outside of specially favored locations. The total cost of operation of one of these machines is given as $2396.84, which, with depreciation and interest on the investment of $447, brings it to $2843.84. These trucks each displaced two 2-horse wagons costing $3605.76 for labor and $1252 for general maintenance, no allowance being made for depreciation and interest in this case, as no record had been kept of the original cost of the equipment.

TABLE IX

Expense of Operating Electric Commercial Vehicles

Items of Cost	Capacity, Pounds				
	850–1000	1500–2000	2500–3000	4000	7000
Interest and depreciation (machine less batteries and tires)	$244.50	$306.30	$391.40	$ 422.94	$ 470.84
Mechanical and electrical upkeep	67.54	84.15	101.70	110.96	121.42
Tire repairs and renewals	79.28	97.30	155.05	267.60	535.25
Battery repairs, cleaning and renewals	130.50	175.36	219.54	271.54	312.84
Current at 1 cent per kw.h.	20.00	30.20	40.00	60.00	51.50
Totals	$541.82	$693.31	$907.49	$1133.04	$1491.85

Without including these items, the net saving of the 5-ton electric truck over the horses was $2460.92.

Costs for Various Sizes of Electrics. Table IX, compiled from the records of a large firm using a number of both gasoline and electric vehicles, shows the detailed costs of operating various sizes of the latter type of units.

Data on Electrics from Central Stations. The most complete and dependable data on this important subject, however, has been that compiled by the central electric stations and given in the following charts: Table X shows the extremely rapid growth of the adoption of the electric vehicle, together with the average cost of current in five large cities in the East, while Table XI gives complete itemized figures for the operation of seven different sizes of electric

TABLE X

Chart Showing Growth of Central Station Electric Vehicle Business

Name of Company	Electrics Operating in Territory		Electrics Charged Central Station Service		Per Cent of Total No. of Electrics on Central Station Service		Charging Current Sold Kilowatt Hours		Average Rate per Kilowatt Hour	
	1912	1913	1912	1913	1912	1913	1912	1913	1912	1913
United Electric Lt. & Pwr. Co.			104	124			286,113	537,678	3.409	3.48
Public Service Electric Co.	422	472	352	400	95	88	644,500	1,043,500	3.65	3.37
Edison Electric Illuminating Company of Boston	327	463	311	447	95	96	774,202	1,351,965	3.61	2.83
Potomac Electric Power Co.	758	950	678	860	91	91	1,470,443	1,927,730	3.62	3.54
Commonwealth Edison Co.	2,135	2,829	1,155	2,070	54	73	3,000,000	6,500,000	4.33	3.08
The New York Edison Company	1,640	2,070	815	1,100	50	53	3,830,500	5,500,000	4.50	4.21

vehicles, from the lightest to the heaviest, in ten different classes of service; Table XII details the fixed charges in an equally complete manner.

Depreciation. This has been defined as the diminution which takes place in the value of a wasting asset in spite of the amount expended on it for repairs, and there is no doubt that in assessing the diminution in value of commercial vehicles something more than the application of definite accountancy principles is necessary. The first factor to be considered is the estimated working life of the machine, and this depends very largely on the nature of the service. For example, a London bus runs some 700 miles a week; on the other hand, a merchandise-carrying vehicle may run from 150 to 350 miles a week, but it is scarcely apt to exceed the latter figure and will equal it in only a few instances. Obviously, the working life of the latter type would be much longer than a chassis of the same make run as a bus. Working life also depends upon the quality of the vehicle, which connects it with the initial cost and, further, upon the condition in which the vehicle is maintained, and this in turn depends upon the driving, supervision, and regularity of making repairs and renewals.

Method of Calculation. Having fixed an estimated working life, L, some method of apportioning this over the period in question must be adopted, in other words, a method of writing off the depreciation year by year. The following methods of doing this are in more or less general use.

(1) To divide the capital outlay C, by the number of years estimated for the total working life and charging the quotient against each year's working costs.

(2) In the first year to write off a high percentage of the cost, and in each succeeding year to write off the same percentage of the diminished value, i.e., the balance left after deducting the previous year's depreciation.

(3) To divide the capital outlay C, less residual value R (that is, the estimated value of the vehicle at the end of its working life) by the number of years.

In each case, renewals and repairs as they occur are charged against general running expenses. The first method naturally cannot be recommended where any degree of accuracy is required. In

TABLE XI
Electric Vehicle Operating Cost Chart

PERFORMANCE DATA											OPERATING EXPENSE											
											OIL		CURRENT		TIRES		BATTERY		MECHANICAL PARTS		REPAIRS LABOR	
Rated Carrying Capacity	Type of Battery	Period Covered by Data	Total Mileage	Total Kw. Hours Used	Kw. Hours per Vehicle Mile	Cost Current per Kw. Hour	Days Used	% Total Working Time Used	CLASS OF SERVICE	Ave. % Grades	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile
700	Lead	1 Yr.	5518	3224	.585	$.0300	280	89	Distribution and Construction	4%	$ 4.35	$.0008	$ 96.72	$.0175	$ 24.38	$.0044			$500.83	$.0909	$203.63	$.0369
700	Lead & Edison	3 Yrs.	17335.5	10074	.581	.0400	895	80.6	Delivery	2%	4.47	.0008	268.64	.0465	60.46	.0105	$119.86	$.0215	79.43	.0138	17.17	.0030
1000	Lead	2 Yrs.	419510	257685	.6140	.0335	670	92	Mail Delivery	2%	205.44	.0010	4316.21	.0206	2055.47	.0098	6053.01	.0289	4438.05	.0212	1913.46	.0091
1000	Lead	1 Yr.	10097	7397	.733	.0300	279	89	Distribution and Construction	4%	9.30	.0005	221.91	.0220	274.44	.0272			465.04	.0461	427.72	.0424
1000	Lead & Edison	3½ Yrs.	62312	31737	.509	.0400	1046	81.9	Delivery	2%	10.25	.0006	362.71	.0207	145.09	.0081	747.96	.0420	2730.93	.0130	77.37	.0043
2000	Lead	2 Yrs.	134161	82408	.615	.0335	670	92	Mail Delivery	2%	65.17	.0009	1380.33	.0207	958.80	.0143	1915.68	.0286	1227.95	.0183	572.86	.0085
2000	Lead	1 Yr.	8691	7110	.818	.0300	234	75	Distribution and Construction	4%	9.08	.0010	213.30	.0245	33.62	.0039			91.64	.0105	316.99	.0365
2000	Lead	6 Mos.	30773	18918	.617	.0300	164	100	Pick-up and Delivery	2%	6.36	.0001	1135.98	.0185	1823.26	.0297	686.20	.0112	571.88	.0093	745.58	.0121
2000	Lead & Edison	3½ Yrs.	44307	35994	.815	.0400	1186	92.9	Inspection & Emergency	2%	7.98	.0006	411.36	.0327	166.52	.0132	595.00	.0470	86.22	.0068	104.66	.0083
3000	Lead	1 Yr.	6192	4866	.788	.0300	240	96	Delivery		3.96	.0006	145.98	.0236	198.12	.0320	200.28	.0324	141.00	.0227		
4000	Lead	2 Yrs.	71802	61763	.860	.0335	670	92	Mail Delivery	2%	39.89	.0011	1034.53	.0288	755.69	.0210	1353.75	.0377	729.55	.0203	357.33	.0099
4000	Lead	1 Yr.	4553	4507	.898	.0300	246	98	Delivery		3.00	.0006	135.21	.0297	196.44	.0432	309.48	.0680	99.72	.0219		
4000	Edison	1 Yr.	5817	6950	1.195	.0300	240	96	Trucking		2.64	.0004	208.51	.0358	152.76	.0263	37.92	.0065	66.44	.0114		
4000	Lead & Edison	3½ Yrs.	27653	26816	.970	.0400	1080	83.5	Delivery	2%	5.06	.0006	306.47	.0388	269.11	.0365	251.28	.0318	92.02	.0117	66.41	.0084
7000	Lead	1 Yr.	7729	10290	1.298	.0100	299	96	Meat Delivery		3.63	.0005	93.54	.0121	254.46	.0329	259.45	.0336	446.74	.0578		
7000	Lead	3½ Yrs.	10591	12688	1.197	.0400	1070	83.8	Trucking and Cable Pulling	2%	2.78	.0009	114.95	.0479	123.15	.0407	266.94	.0882	19.02	.0063	13.43	.0044
10000	Lead	1 Yr.	5891	6925	1.175	.0300	248	97	Heavy Trucking		3.00	.0005	207.75	.0353	193.44	.0328	221.52	.0376	97.36	.0165		
10000	Lead	3½ Yrs.	11058	15529	1.406	.0400	1069	83.4	Trucking and Cable Pulling	2%	2.90	.0009	178.90	.0569	162.28	.0577	315.81	.1000	20.99	.0067	12.80	.0041

TABLE XII

Fixed and Overhead Expense

RENT		GARAGE				SUNDRIES		DRIVER		AMORTIZATION		INTEREST		FIRE INS.		LIABILITY INS.		ADMINISTRATION		TOTALS	
		Supervision		Labor																	
Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Yearly Cost	Vehicle Mile	Per Vehicle per Year	Vehicle Mile
		$ 89.65	$ .0162	$ 82.38	$ .0149	$ 100.81	$ .0182			$ 150.00	$ .0272			$ 8.10	$ .0015	$ 60.75	$ .0110			$1321.60	$ .2395
$ 315.08	$ .0545			218.17	.0378			$1194.00	$ .2068	322.33	.0558	$ 96.93	$ .0168	51.78	.0090	212.47	.0541	$ 49.30	$ .0085	1505.06	.5211
1421.16	.0067	1254.51	.0060	3055.33	.0146	4111.86	.0196	11708.23	.0558	9788.04	.0466	1601.73	.0076	217.00	.0010	3995.08	.0191	2165.93	.0103	3429.44	.2799
		156.34	.0155	159.76	.0158	204.93	.0203			440.00	.0436			21.60	.0021	121.50	.0120			1251.27	.2478
695.26	.0391			503.57	.0283			2391.43	.1344	880.00	.0495	264.00	.0148	120.57	.0068	459.71	.0264	97.26	.0055	1746.52	.3925
441.36	.0065	368.93	.0055	913.82	.0136	1226.88	.0183	3682.69	.0549	3956.28	.0589	648.06	.0097	86.94	.0013	1175.02	.0175	636.99	.0095	3851.51	.2871
		117.84	.0136	118.77	.0137	157.24	.0182			520.00	.0598			36.00	.0041	121.50	.0140			1397.22	.1998
2395.62	.0390	961.20	.0156	1922.44	.0313	1404.92	.0228	6992.50	.1136	1967.36	.0320	1180.42	.0192	135.00	.0022	850.50	.0139			2531.02	.3705
639.73	.0505			428.00	.0339			2540.71	.2000	876.50	.0693	262.95	.0207	127.76	.0101	331.98	.0262	72.94	.0058	2216.10	.5251
75.00	.0121			91.56	.0148	5.64	.0009	582.68	.0940	270.00	.0436	81.00	.0131	24.30	.0039					1819.52	.2937
391.52	.0109	295.08	.0082	669.42	.0186	899.08	.0251	1993.42	.0555	3657.96	.1018	584.69	.0163	78.71	.0022	939.92	.0262	509.12	.0142	3572.54	.3978
75.00	.0165			116.52	.0256	5.52	.0012	644.16	.1414	350.00	.0769	105.00	.0231	31.50	.0069					2066.15	.4550
75.00	.0129			86.56	.0149	8.16	.0014	581.04	.0099	305.00	.0524	91.50	.0157	27.45	.0047					1642.78	.2826
632.71	.0801			260.28	.0329			1543.57	.1954	799.71	.1012	240.38	.0308	117.52	.0149	234.32	.0297	49.57	.0063	2444.23	.6191
		193.88	.0250	Included with Supervision		88.90	.0115	954.32	.1235	253.24	.0328	139.88	.0181	13.00	.0017	63.09	.0082			2764.12	.3576
378.65	.1251			146.85	.0486			917.14	.3030	455.00	.1505	136.43	.0451	66.17	.0219	114.93	.0380	24.31	.0080	2809.82	.9286
75.00	.0127			116.52	.0198	12.00	.0021	1159.56	.1966	490.00	.0832	147.00	.0250	44.10	.0075					2767.25	.4696
465.91	.1475			146.57	.0464			916.28	.2900	512.00	.1621	153.87	.0487	75.85	.0240	115.77	.0367	24.43	.0052	3104.36	.9835

Tables compiled by the New York Edison Company.

that it gives the actual reliable value at any time during its life, the second method is perhaps the soundest financially. Although this method gives a fairly true result in the end, it has the objection that, in its earlier years the cost of the service is overloaded.

The third method, expressed by the formula $\frac{C-R}{L}$, in which C is the capital outlay or initial cost, R the residual value, and L the estimated working life, is recommended as being the most practical and accurate. The only observation necessary on this method is one dealing with the reconsideration of L at a later period. When the life of a vehicle is reconsidered, the *unexpired capital outlay* should be taken as the basis for the revised charge for depreciation. Thus assume the above formula as $\frac{5000-500}{5}$, in which \$5000 is the initial cost of the vehicle, and \$500 its estimated value at the end of five years, the annual depreciation being \$900. At the end of the second year the capital outlay should have been written down to \$3200. If the estimate of the working life be then revised and extended to seven years, with five more to run, then $\frac{\$3200-\$500}{5}$ equals \$540, annual depreciation.

Obsolescence. Obsolescence is a factor which has to be considered, as it is by no means improbable that some combination of circumstances may make it desirable to dispose of a particular vehicle before it is really worn out. From a strict accounting point of view, obsolescence may not be depreciation, but it is at least of sufficient importance to "round up" any percentage that may be determined by other considerations. If, in the future, by greater perfection of design the ordinary working life can be estimated as longer than at present, obsolescence will become of more importance, for a machine which is still quite efficient mechanically may be rendered uneconomical by the introduction of improved types.

A detail that has not been referred to in the foregoing is the method followed with regard to small additions to plant. The effective life of these additions may or may not be co-terminous with that of the vehicle, and any attempt to bring their depreciation within the system outlined for the vehicle itself would involve complications which it would not be worth while to incur. The most convenient method of disposing of such items is to write them altogether in the year of their purchase.

MANAGEMENT

Importance of Efficient Management. The discussion of the taxicab has revealed the fact that the success of a commercial vehicle in service depends to no little extent upon its operation. The designer has made every effort to reduce its mechanism and control to such absolute terms of simplicity that little or no discretion is left to the driver, but it is nevertheless out of the question to eliminate the personal equation entirely. The electric vehicle means the closest approach to this ideal, and therefore has an advantage where the grade of labor to be employed is in question. The training of a sufficient number of men to properly handle gasoline trucks has presented a real problem, which has been rendered far more difficult by the lure of pleasure-car service at rates of compensation beyond the standards permissible in the commercial field. Thus, many drivers, once they had mastered the handling of a truck, immediately deserted this field for the much higher compensation of a chauffeur's position, and the process of training had to be repeated, often to the detriment of the vehicle itself.

Drivers. While the man at the wheel is an element which neither the designer nor the builder of the machine can reduce to engineering practice, he is such an important factor in the operation of the machine that it behooves the owner of the truck to exercise the care in his selection and training consistent with the large amount of capital he has invested in this form of transportation and its cost of maintenance. That this has not always been done is only too evident from the long record of unsatisfactory service and damaged machines which have acted as a setback to the legitimate development of the commercial vehicle. The great body of men now serving in this capacity has been drawn from two sources, the professional chauffeur, who has had his training on high-speed pleasure cars, and the ex-horse driver.

Experience would lead to the conclusion that, of the two, the latter is far to be preferred. While the professional chauffeur is usually a good mechanic, in fact, often an expert capable of taking care of almost any derangement that can be handled outside of a repair shop, he is accustomed to far greater speeds and to expense accounts that bear no direct relation to the service rendered. There are a hundred and one ways in which he can help or hinder the work, and he can naturally make or mar the mechanical reputation of the car. He is apt to feel that he has lost caste by driving a commercial vehicle, and when the results of abuse become apparent is likely to attribute them to defects in the vehicle itself rather than to his handling of it. On the other hand, a good man taken from the seat of a horse-drawn truck is valuable from the start, because he knows merchandise transportation and is already familiar with his employer's goods and business methods. His elevation to the wheel of the motor truck is in the nature of a promotion and brings with it increased pay, which makes him contented—something that can hardly be overrated. Knowing nothing of the mechanical intricacies of the machine, he has a greater respect for it and is not prone to tinker with it, nor to let obvious derangements go without reporting them. With the professional chauffeur, driving a truck means lower pay and much harder work, and his dissatisfaction with his lot is taken out on the machine itself, which suffers correspondingly.

QUICK LOADING AND UNLOADING

Cutting Idle Time. Motor trucks of heavy carrying capacity represent so much greater an investment than even the largest horse-drawn units, that idle time must be reduced to a minimum to insure their operation on an efficient basis. It is not always possible to minimize what is usually termed idle time, i.e., time lost at freight terminals in waiting to load or unload, as this is usually controlled by outside factors; but, as the chief advantage of the motor truck lies in its ability to carry a greater load at a greater speed, its earning power is largely governed by its daily mileage, and as the time necessary to load and unload determines this to a large extent, every effort has been made to cut it down to the minimum. With a horse-drawn truck earning $20 a day, the saving of 25 per cent of the loading and unloading time is a small item as compared with the same percentage of the operation of a motor truck which is worth $40 to $50 a day. The driver's time is likewise a factor in computing this cost, and as the wages paid are very much higher in this country than abroad, the practice of quick loading and unloading has perhaps been developed to a greater extent here than in Europe.

Modern facilities for dealing mechanically with the loads of commercial cars practically group themselves under two heads—those for unloading only and those which can be employed for both loading and unloading. As the latter phase of the problem is the only one which concerns the mechanism of the truck itself, no reference is made to the former in this connection. Naturally, only certain forms of materials lend themselves to the methods of handling in quick unloading—which usually means dumping—such as coal, sand, rock, ore, and building materials generally. The hand-

Fig. 339. Jeffery "Quad" Truck with Hand-Tipping Mechanism

operated tilting body for coal wagons has been with us for a generation or more, so that the application of the same practice to the motor truck is scarcely novel. But the latter is not applicable to trucks of more than one or two tons' capacity at most, whereas a tipping gear is seldom applied to motor trucks of less than five tons' capacity.

Requirements. To unload the truck body quickly and completely without resort to any hand labor, and without employing a special frame or body design which represents a radical departure from a standard practice, usually calls for an end-tipping arrangement. If it were possible to balance the body at the center and always load it evenly, a comparatively light handgear would be sufficient to lift it; but in the design of the commercial car which has been developed to meet other considerations of operation, it is seldom possible to obtain such conditions, owing to the necessity for avoiding an excessive overhang at the rear unsupported by the frame. Consequently, it is usually necessary to pivot the body quite a little distance back of its center, and this places a heavy load on the elevating gear. This is exemplified by the illustration of the Jeffery Quad truck with hand-tipping mechanism, Fig. 339, which

Fig. 340. Standard Hand-Operated Lifting Body to Deliver at Right Angles

shows how close to the rear end it is necessary to pivot the steel body in order to make the balance correct.

The limitations of narrow city streets with street-car tracks in them frequently render it necessary to have the truck dump from the end, while the machine itself stands parallel to the sidewalk and close to the curb. One method of accomplishing this is shown by Fig. 340, which illustrates a Standard 5-ton truck with body mounted on a special sliding frame independent of the truck frame itself, and carrying the hoisting gear with it. It will be noted that, to enable this to be done by hand power, two or three gear reductions are necessary and the process is correspondingly slow. But unfortunately the design of the motor truck does not lend itself readily to the use of a side-tipping body which will empty its load quickly by gravity, though no unusual mechanical difficulties are presented by the problem of hinging the body at its side instead of at the end, and of arranging the gear to tilt it sideways. The chief drawback is that an unusual height of body would be necessary to make the discharge converge at one point by means of a sloping inside bottom, a requirement which is necessary in the city delivery of coal.

An ingenious solution of the problem is presented by Fig. 341, which shows how the requirements in question were met with a

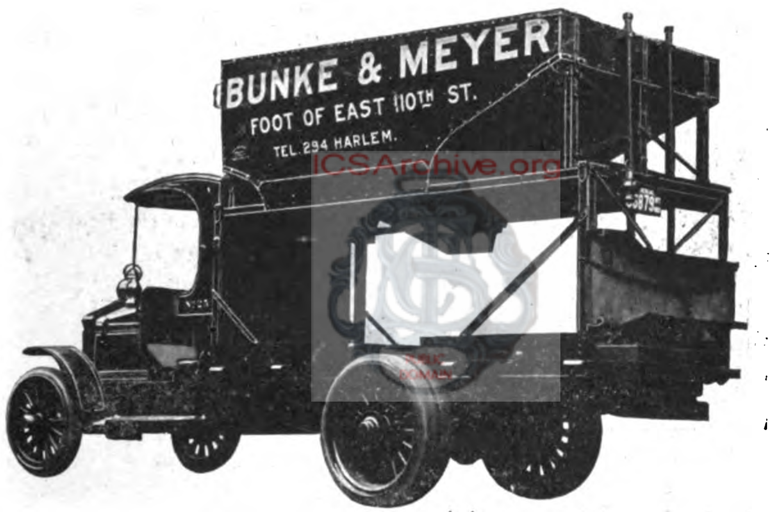


Fig. 341. Elevating Body for Side Delivery

5-ton Pierce-Arrow worm-driven truck. The steel body slopes from both ends toward the center, meeting in a channel-shaped depression at the lowest point, from which a chute may be extended for delivering the coal directly to a manhole at some distance from the curb line. This extension chute is shown attached to the rear of the truck. Instead of being either permanently attached to the chassis frame or pivoted to it, the body is designed to move vertically in slides formed by a rectangular framework, and for unloading is elevated several feet above the chassis by means of a geared mechanism driven by the motor. Only a few minutes are required to raise the body, discharge the load, and lower it again to its normal position.

Hand-Operated Mechanism. Hand-operated tipping gears are more commonly used abroad than in this country, the most usual type being what is known as the telescoping screw. This consists essentiallv of a heavy screw or screws—two being used for a heavy truck—pivoted at their lower ends by means of trunnions which carry the operating nuts, so that the screws may accommodate themselves to varying angles while the body is being elevated. The lifting screws are rotated through a transverse crankshaft and bevel gears, the whole mechanism being arranged to swing with the lifting screw on its pivot. One of the simplest types of British tipping gears is the Mann pin-rack mechanism, in which the usual lifting screws are replaced by steel pin-racks kept in mesh by suit-

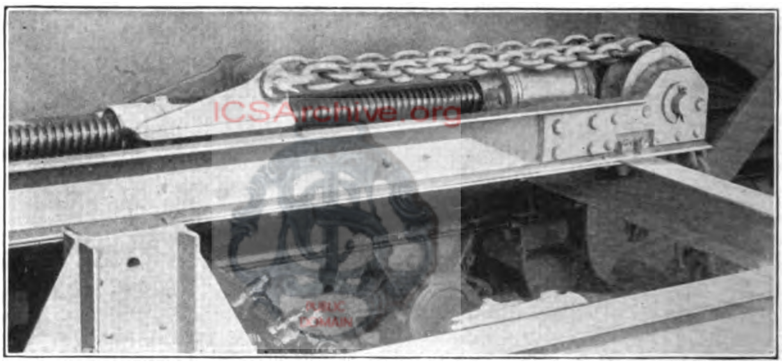


Fig. 342. White 5-Ton Truck Power Dumping Mechanism

able shackles, with the pinions secured on a horizontal transverse shaft turned by a hand crank. In addition to its simplicity, this is proof against interference with its action by dirt, as any obstruction of this nature is forcibly pushed out of the rack by the teeth coming into engagement. A more elaborate modification of the same type of body, and one often adopted on the Continent, especially in Germany, consists of two heavy quadrant-shaped racks secured to the under side of the body and operated by hand-rotated pinions on a horizontal cross shaft working through suitable reducing gearing.

American Practice. *Screw Type.* The majority of American heavy trucks designed for carrying material adapted to this form of rough handling employ either a mechanical or hydraulic form of mechanism designed to tip the body endwise. The advocates of both types seem to be about equally divided, although apparently there are more mechanically operated tipping bodies in service.

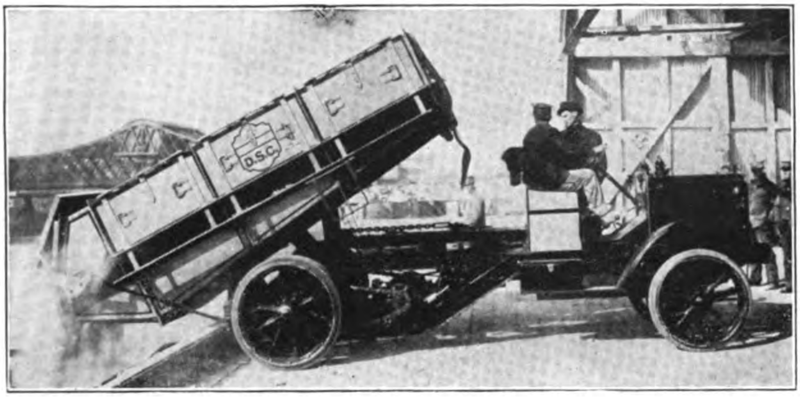


Fig. 343. Driver Discharging Load without Leaving His Seat, White 5-Ton Truck

The latter type usually takes the form of a long screw and nut, the screw being driven through gearing meshing with either the low-speed or reverse of the transmission. Attached to the nut are

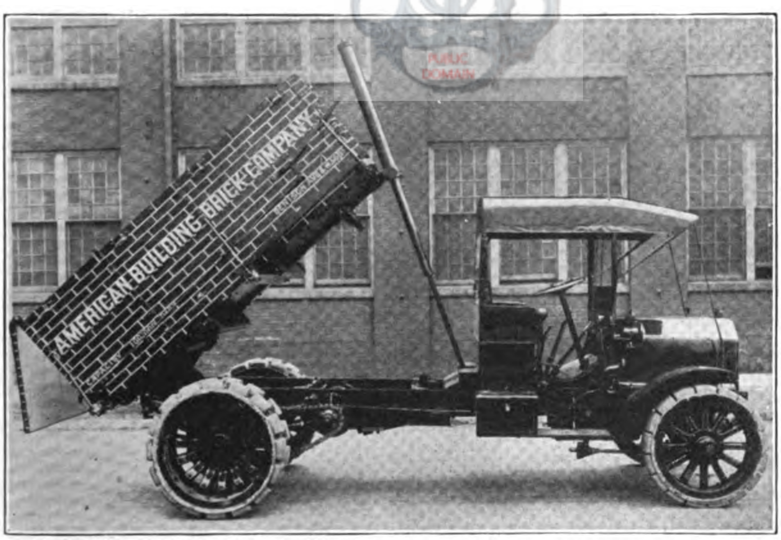


Fig. 344. Telescoping Screw Type of Tipping Mechanism, Peerless 5-Ton Truck

chains or steel cables running over sheaves and designed to elevate the body by means of levers or quadrants. The details of the mechanical body-tipping gear are shown by Fig. 342, the screw in this case lying horizontal and being carried on a special sub-frame over the center of the main chassis frame. The operating gear is engaged by the driver, as shown in Fig. 343, which illustrates a 5-ton White truck employed by the New York street-cleaning department. As the door of the body is also raised simultaneously by the mechanism, the driver can dump the load, return the body to its running position, and start off again in little more than a minute, without the necessity of leaving his seat.

A variation of the application of the screw mechanism is illustrated by Fig. 344, which shows a 5-ton Peerless truck for carrying

Fig. 345. Lacre (British) Tipping Wagon, Telescoping Screw Type

rough brick. In this case the screw is attached directly to the body and, in order to give the necessary elevation to overcome the "angle of repose" for this class of material, is of the telescoping type. That is, there are two screws, one of which is hollow. In operation, they are driven through bevel gearing, chains, and sprockets from the transmission in a similar manner to that already outlined. The inner screw first runs out as far as it will go by using the hollow screw on it as a nut. It then locks the hollow screw and turns the latter, which continues to elevate the body by using the threaded protective housing as a nut. When the body is returned to its normal level, both screws telescope in the tubular housing which protects them from dirt. Fig. 345 shows a Lacre (British) truck with a similar form of tipping mechanism.

Angle Extensions and Chains. On the Vulcan 7-ton truck,

Fig. 346. Sprocket-and-Chain Tipping Mechanism, Vulcan 7-Ton Truck

which is shown dumping its load in Fig. 346, a totally different principle of mechanics is employed. Triangular extensions form the necessary levers, which are attached at their lower ends to endless

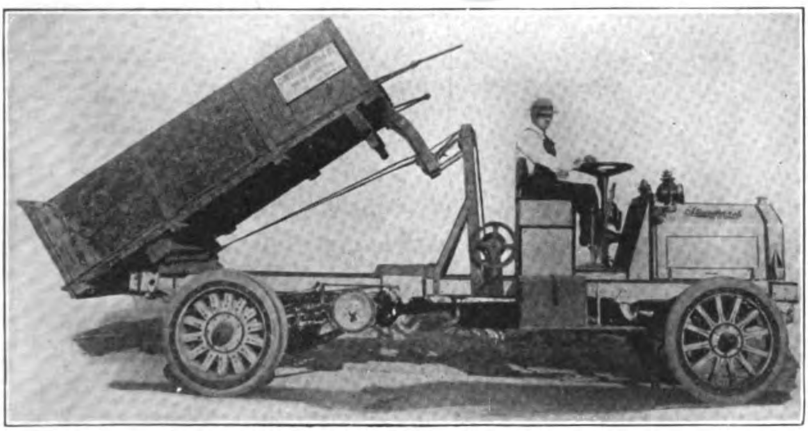


Fig. 347. Drum-and-Cable Tilting Mechanism, Standard 5-Ton Truck

chains. These chains run on heavy sprockets attached to parallel shafts which are carried on a vertical steel frame just back of the driver's cab. The lower shaft is driven through reducing gears from the motor, and its rotation carries the chain around, lifting and depressing the body as shown. A short hand lever—such as will be noted just back of the emergency-brake lever on the Peerless truck—is usually employed for meshing the operating gears of mechanically driven tilting mechanisms.

Winch Form. Still another form of this type is illustrated on the Standard 5-ton dumping truck, Fig. 347. This is nothing more nor less than a winch of the hoisting type, the steel cables of which are attached to lever arms extending downward from the lower surface of the body. Additional leverage is obtained by carrying

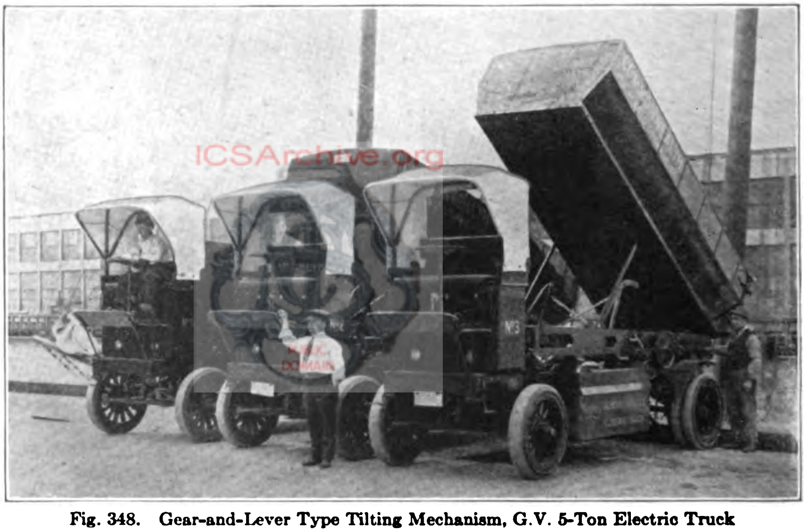


Fig. 348. Gear-and-Lever Type Tilting Mechanism, G.V. 5-Ton Electric Truck

the steel hoisting cables around sheaves on these levers and back to the pivoting bar of the body, where they are made fast in the same manner as the effort exerted is geared down and multiplied in an ordinary rope tackle having multiple sheaves.

Gear Type with Electric Motor. Another variation of the gear type of lifting mechanism is shown on the 5-ton G. V. electric coal trucks, illustrated by Fig. 348. This is operated by a special electric motor installed for the purpose and controlled from a point near the end of the truck, the details of the mechanism and its method of operation being clearly shown by the illustration.

Hydraulic Types. In the hydraulic types, a small oil pump driven by a roller chain from the crankshaft of the motor develops pressure which is utilized in a vertical hydraulic cylinder designed to elevate the body by means of steel cables and sheaves, as shown by the detail view of the mechanism of this type as installed on a Pierce-Arrow truck, Fig. 349. The pump being thrown into gear, the pressure is controlled by the small hand lever shown in the foreground, the operation of tilting the body of this type being illustrated by Fig. 350. At the time this picture was made traffic conditions were such, owing to a heavy snowstorm, that horses could not be employed at all.

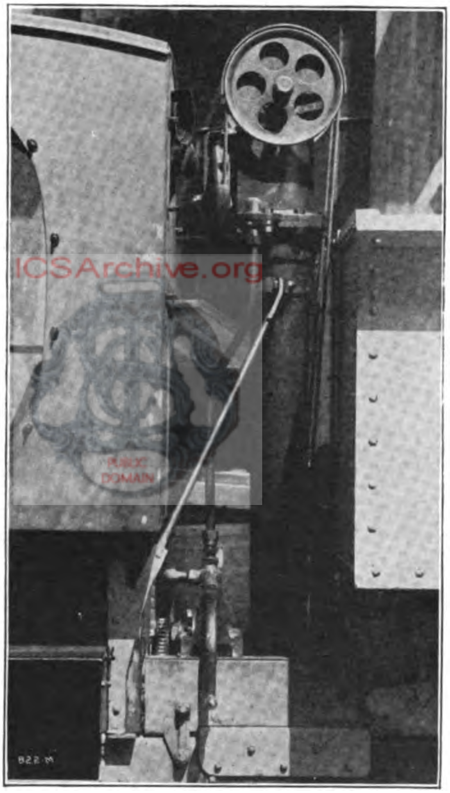


Fig. 349. Hydraulic Tipping Gear, Pierce-Arrow 5-Ton Truck

The mechanism operating the Pierce-Arrow hydraulic hoist is run from a forward extension of the countershaft of the transmission. On this shaft are mounted a chain sprocket and driving clutch, the sprocket being carried on two ball bearings, so that the shaft may run continuously while the sprocket is idle. The clutch is secured to the shaft by a key and is controlled by a small lever near the driver. This causes the clutch to slide along the shaft and engage the sprocket, which drives the rotary gear-type oil pump and at the same time releases the locks holding the body in place and letting it swing free on its rear hinge. One of these locks will be noted on the side of the body in the detail view. The pump is connected to the cylinder of the hydraulic ram by a suction pipe entering at the top. Oil is drawn from this point and forced in below the piston, which rises under the pressure until the end of the stroke is reached, at which point a striker plate trips three valves in the piston. This opens them and permits the oil to escape freely from the lower to the upper part of the cylinder, thus equalizing the pressure and holding at rest the load as represented by the now elevated body. The actual lifting is accomplished by the flexible steel cable passing over two sheaves at the sides and under a third central sheave at the rear. The former multiply the movement, giving two feet of lift for every foot traveled by the piston of the

Fig. 350. Pierce-Arrow Hydraulic Tipping Gear in Operation

ram, while the third sheave acts as a compensating device, equalizing the lifting force on both sides of the body.

The operation of a similar type of elevating mechanism as applied to a Packard 5-ton truck is shown in Fig. 351. In this case, the control is by means of a small double-ended lever working both ways on a panel at the side of the driver's seat, as indicated by the dark semicircular section.

Detachable Bodies. To obtain the same economy of quick loading and unloading with merchandise, which does not permit of dumping either into or out of the truck, it is customary to resort to duplication of the bodies, either as complete units or as detachable carriers designed to run on rails on a platform body permanently attached to the truck. In either case, the bodies are made interchangeable, and the methods of fastening are such that the shift from one to the other requires only a few minutes. An English furniture manufacturer, with stores and warehouses in the East End of London and a factory at Kingston-on-Thames sixteen miles distant, operates a system of this kind very economically. The truck employed is a 3-ton Thornycroft steamer with removable body mounted on rollers. On its arrival at either end, the loaded body is run off onto the loading stage and another body, which had been loaded while the car was on the road, is promptly run onto the

Fig. 351. Packard Truck with Hydraulic Tipping Gear

chassis, and the vehicle gets away again with practically no loss of time. As the same thing happens at both ends, the car is constantly on the road, and the capital which it represents is utilized to its full effectiveness. In fact, two trucks would be necessary to do the work of this one machine were the old methods of loading and unloading in force. Operation according to this system is usually made most efficient by the provision of special loading stages, but where they are not available cranes are employed to lift the bodies on and off the chassis.

A system of this kind has been developed in this country by the builders of the Locomobile trucks, Fig. 352. Bolted to the side members of the frame of the truck are two deep channel rails in which eight sets of rollers run, four on each side. These rollers have large plain bearings lubricated by grease cups, and any two of them are capable of sustaining the entire load. They are attached to the under side of the demountable bodies. A heavy screw as long as the chassis itself is mounted centrally between the two channel rails, and on it is a large nut which moves forward or backward according to the direction the screw is rotated. This nut travels in guides, which keep it in alignment, and has a saddle hook and a swiveling pressed-steel drawbar attached to it. The operating lever is controlled from the driver's seat, and is similar to the usual selective gate of the gear-shifting lever. The screw is driven from the

Fig. 352. Combination Dumping and Detachable Body, Locomobile Truck

transmission and, throwing the lever to one side of neutral, causes the nut to travel forward. By attaching the drawbar to a body on the loading stage, it is drawn on to the chassis. Putting the lever over to the other side reverses the screw and moves the nut backward; automatic trippers limit its travel in either direction and prevent overriding the screw or jamming the nut. The channel rails mentioned have cradle-shaped depressions at their rear ends, so that the body may be pushed off on to a loading platform or be dumped without leaving the chassis. In dumping, as there is no platform to support the rear end of the body as it is pushed backward, the weight forces the second pair of rollers into these depressed cradles. This slightly raises the front of the body, which is further forced up by the travel of the nut.

ABUSES

Overloading. Of all the abuses inflicted on the motor truck by the ignorant, indifferent, and careless driver, and not infrequently, by the owner, overloading is the worst and produces the most serious effects. It is also one of the most difficult things for the manufacturer of the car to guard against, and the practice is so common that the only protection the maker has is to state explicitly that overloading will cancel the guarantee. Two things are responsible for the abuse—the willingness of the salesman to promise almost anything in the way of performance, and the desire of the owner to get the greatest return for the investment. The latter cause frequently leads to overloading in an emergency on the theory that "just this once doesn't count", although the custom of making exaggerated promises is a most prolific cause. The purchaser has been led to believe that the truck will displace a larger number of horses than the facts warrant, and he immediately proceeds to obtain the maximum results by going ahead on this assumption. Horses will collapse or refuse to move the load when overburdened, but the truck cannot protest except by giving way, and then the damage is done. Many trucks are accordingly subjected to service far beyond their capacity with the result that they quickly become less efficient and soon fail to such an extent that expensive repairs are required. Under the guarantee of sale their cost should be borne by the maker, but investigation often reveals abuse on the part of the owner, and any settlement will result in dissatisfaction.

One example will suffice to show the extent to which this overloading is sometimes carried. A high-grade machine with a nationwide reputation for service and durability, rated at five tons' normal-load capacity, was sent out in the usual routine. Before going very far it stopped and examination showed that the rear axle was badly bent. An emergency call was immediately sent to the local agent and he offered to deliver the load which, upon being weighed—it was carried in three trips instead of one as attempted by the owner of the disabled car—proved to slightly exceed ten tons. As an examination proved that the damage was merely the culmination of a regular practice of overloading, the owner was compelled to stand the expense of repairing the machine. Naturally, every case is not as clear-cut as this; that is, while it is patent to experienced eyes that overloading is the cause of the damage, it is not easy to convince the owner that he has been at fault. Body capacity is usually so much in excess of weight-carrying capacity in the average truck that it is nothing uncommon to measure the ability of the machine by the bulk rather than by the weight.

It must not be concluded from this that the user of the truck is to blame in all cases, as there are many instances in which the manufacturer himself has overrated the ability of his product. The commercial-vehicle field has appeared so tempting from an investment point of view that numerous poorly designed machines have been marketed by organizations of little experience in their manufacture, and in order to meet competition it has been usual to overrate the capacity. This has been the case particularly with lighter vehicles. Of twelve different makes rated at 1½ tons' capacity examined at an automobile show the weights ranged from 3750 to 5700 pounds. Bearing in mind the factor of load efficiency—i.e., as the capacity of a vehicle decreases its weight must be proportionately greater and a load efficiency approaching 100 per cent is only attainable in machines of five tons' capacity and over—it is difficult to reconcile a 1½-ton rating for one vehicle weighing 3750 pounds with one weighing one ton more. Doubtless all of the trucks in question could carry 1½ tons without breaking down, but it will be obvious that the lighter machines will not continue to do so with the same dependability as those in which a more liberal allowance of material and tires has been made. Furthermore, the repair and upkeep expenses of the lightly built trucks over a period of years will be disproportionately high.

Speeding. From the engineer's point of view, speeding is simply overloading in another form, and is even more damaging to the vehicle than the practice of carrying excessive loads at normal speeds, as the striking force of an object is equivalent to its weight times its velocity squared. Consequently, it results in the mechanism being pounded that much more severely, with the result that loose parts and broken springs and axles are not uncommon. Unfortunately, it is equally bad with light loads, as the shock-absorbing ability of the solid rubber tires is limited, and beyond a certain point their cushioning effect is totally lost. The use of a governor which limits both the speed of the motor and the speed of the vehicle,

TABLE XII

Maximum Speeds for Commercial Vehicles

Pounds Capacity	Miles Per Hour	Pounds Capacity	Miles Per Hour
1000	16	10000	9
2000	15	11000	8½
3000	14	12000	8
4000	13	13000	7½
5000	12	14000	7
6000	11	15000	6½
7000	10½	16000	6
8000	10	18000	5½
9000	½9	20000	5

as outlined in the section on "Motor Governors" is a preventive of this, but as few of the many thousand trucks already in service are thus provided, a schedule of maximum speeds for the various sizes of vehicles has been adopted. This is shown in Table XIII.

It is evident that the remedy for these abuses lies entirely within the province of the truck owner. Large "fleets" of trucks operated by corporations are almost without exception the best kept, the most reasonably maintained, and are operated with the highest economy, simply for the reason that the business principles of the corporation are broader and are more carefully applied. A competent expert is put in charge of the trucks and the drivers are not expected to make adjustments or repairs. Where only one or a few trucks are operated, the driver is usually called upon to inspect and repair his machine within the limits of his ability, as well as to run it. Very often this is too much for human endurance, as many drivers are out from an early hour until late at night. Doubtless 90 per cent of the dissatisfaction with motor trucks is due directly to insufficient attention of driver, maintenance, care, and operation.

As a check upon the overloading evil, the shipping departments of some large motor-truck users have installed weighing systems, whereby the load of each truck is weighed almost as carefully as if it were being shipped by express. One follower of this system reports that since installing it an increase of from 1200 to 2000 miles in tire service has been experienced, which involved a saving of $3500 per year on tires alone. Truck maintenance likewise decreased $15 per month on the average, which increased the saving another $1500 per year. The extra time required for weighing the loads did not amount to more than $300 a year in labor charges and provided valuable data on the user's transportation requirements. This is an example of the value of taking the delivery department out of the field of guesswork or rule of thumb and putting it on as systematic a basis as any other department of a large business.

Recording Instruments. Despite the numerous checks upon the operator embodied in the construction of the truck itself, leaving but little to his discretion in its actual management apart from running, it is evident that once away from the home establishment the driver is in absolute possession and the owner must rely upon his integrity to give a truthful record of its performance. In the management of a large fleet of vehicles the personal equation becomes a factor of too great importance to permit entire dependence being placed on the drivers, and instruments have accordingly been developed to furnish a record of the vehicle's movements during every moment it is in service. These instruments are also of great value in providing accurate data upon which to base the regulation of extensive delivery systems in order that the maximum efficiency may be attained.

Mileage recorders have been in general use on commercial vehicles for several years, but it will be evident that while a record of the total distance covered is valuable for checking tire life and other items of maintenance, it falls short of providing all the information necessary. Such instruments have usually taken the form of a hub odometer; in other words, the recording mechanism of the usual speedometer-odometer device commonly employed on pleasure cars, is constructed in such a form as to make it readily applicable to the hub of the front wheel. But what are wanted, quite as much as the distance covered, are the rate of speed and the duration of the stops.

To provide this information, two types of chronographic speedometer-odometer instruments have been devised. These are known as the "speedograph" and the "recordograf", and as their operation is based on the same principles and affords the same form of record of the vehicle's operation, a description of the former will suffice for both. The "speedograph" consists of an endless tape, calibrated in hours and minutes, which is wound from one drum to another by a clock mechanism at a speed corresponding to its divisions. In its passage from the drum carrying the blank tape to that holding the record it passes under a pencil, the vertical movement of which is controlled by the speedometer, while the total mileage is recorded by the usual form of odometer, making it unnecessary to total the distance shown by the daily strips of tape record to arrive at this.

Fig. 353 shows a short section of one of these records taken from the speedograph. When the vehicle is idle the pencil makes a

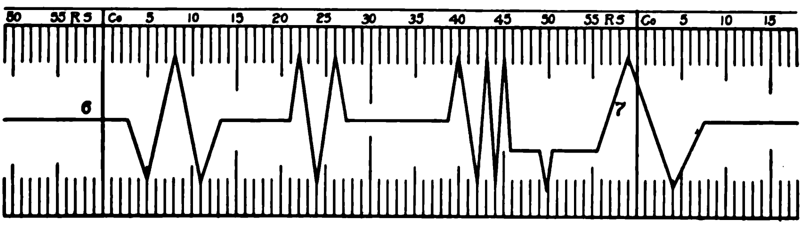


Fig. 353. Section of "Speedograph" Tape Record

straight horizontal line. The tape is divided into minutes and is moved under the pencil at the rate of three inches per hour by the clock, while the speedometer causes the pencil to travel vertically in both directions above and below the horizontal line $\frac{3}{4}$ inch for each half mile, and is operated by the usual flexible shaft drive from one of the front wheels. The record illustrated shows that the vehicle started at 6.03 a. m. and ran $1\frac{1}{2}$ miles at the rate of 10 miles per hour. From 6.12 to 6.21 the vehicle was standing; from 6.21 to 6.27 it ran $1\frac{1}{2}$ miles at the rate of 15 miles per hour, or one mile in four minutes, this being indicated by the spacing of the vertical lines. From 6.27 to 6.39, the vehicle again remained idle. From 6.39 to 6.42 it moved at the rate of 15 miles per hour for $\frac{3}{4}$ mile, and then at the rate of 30 miles an hour for $1\frac{7}{8}$ miles. At 6.46 it stopped for three minutes and then ran $\frac{1}{4}$ mile at a 10-mile rate, stopped five minutes and then ran $1\frac{3}{4}$ miles at the rate of six miles an hour, stopping at 7.08.

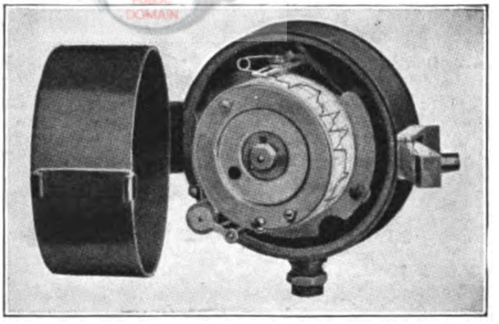


Fig. 354. Open View of "Recordograf"

The "recordograf", as will be noted by Fig. 354, which shows it open, provides a similar record and operates on the same principle, but is constructed in more compact form. At first this instrument was operated by a pneumatic drive, but this was later superseded by the usual form of direct drive from a front wheel. Such records accordingly show the time of leaving the garage in the morning, the time and duration of every stop, mileage between stops, total mileage for the day, the time of returning to the garage at night, and the total distance for the month or year. These records are so accurate that they have been accepted as evidence in lawsuits. In one case in which action was brought for damages for personal injury, the claim was made that the vehicle had been traveling at 30 miles an

Fig. 355. Type of Tape Record Made by the "Recordograf"

hour, but the tape showed a speed of five miles an hour at the time in question and the case was dismissed. The instruments are locked and sealed so that they cannot be tampered with by the driver. Fig. 355 shows a strip of tape from the recordograf. On this, each complete V represents a distance of four miles.

THE MOTOR TRUCK IN WAR

GOVERNMENT SUBSIDY

According to Napoleon, an army "travels on its stomach". This is no less true today than it was at the time the Corsican ravaged all Europe; but today the army's stomach, or all that goes into it, as well as everything else required for fighting, travels on gasoline. Transportation of the huge bodies of men and the tremendous quantities of supplies necessary to keep them in the field would be impossible without the motor truck. Of course, there are not enough motor trucks in existence to transport as large a number of men as constitute any one of the Continental armies, but they have proved valuable for quick movement of small bodies of troops, while for provision and ammunition transport, they have proved indispensable. Foreign governments foresaw this necessity several years before the outbreak of hostilities, and Germany, France, and Great Britain were preparing systematically, for three to five years, for the full utilization of the motor truck as a military transport. For obvious reasons it was practically impossible for the military authorities in any of these countries to purchase outright a sufficient number of trucks of uniform design and maintain them in times of peace. The initial investment required would be enormous, while the depreciation would be correspondingly great, not to mention the cost of keeping in service a sufficient number of skilled chauffeurs to operate them.

These considerations led to the tender by the various governments of subsidies of such substantial importance as to encourage the purchase of motor trucks by private concerns upon conditions which would enable the military authorities to draft them for army use at any time, with the certainty that in the interim they would be kept in good running order and be provided with properly trained drivers.

German Subsidy Plan. In order that the trucks might be used without damage to the ordinary roads and bridges in Germany, and at the same time be available for the roads of neighboring countries, only machines complying with specifications drawn by the government were entitled to the subsidy. The chief of these requirements was a minimum weight of 2 tons and a maximum of 5½ tons on the rear axle; also that the motor be of not less than 35 horsepower. Specifications were also drawn to cover trailers.

The subsidy for each truck amounts to $1190, payable as follows: a premium of $428 upon purchase, followed by four annual payments of $190.50, for the maintenance of each vehicle. If a 3- or 5-ton trailer is provided with the truck, the original payment is raised to $714, and the four annual payments are of $285 each. It was first proposed to distribute the subsidies to private companies only and to make them payable during a period of five years; but this method was altered to encourage the purchase of trucks, so that individual owners might profit by the allowances in times of peace, and that the number available in case of war would be greatly increased.

To insure the maintenance of the vehicles in constant readiness for service, German owners had to comply with a number of regulations, the most important of which were the following:

(1) The vehicles must not be sold or let to concerns in foreign countries.

(2) During a period of five years they must be kept in such a condition that they can be instantly turned over to the military authorities, ready for service.

(3) Accessories, tools, and spare parts must be kept in good condition and be immediately at hand so as to be turned over for use with the truck.

(4) All trucks must be insured against fire and accident and must be stored in a frost-proof garage.

(5) A daily record must be kept of all work performed by the truck.

(6) In the event of war it must be immediately placed at the disposal of the army.

French Subsidy. Having had more experience in the use of the motor truck, France was the first to appreciate the value of the commercial vehicle for military purposes and took up the subject in an experimental manner as far back as 1906. Three years later $375,000 was appropriated for motor-truck subsidies—and 1909 was an early date in the history of the commercial vehicle. However, four years more were required to determine exactly the type of vehicle demanded for motor transport, so that the French system did not come into actual use until about 1913. Meanwhile, Germany had gone in for the idea with the usual Teutonic thoroughness and had its subsidy system well established long before France had got around to putting hers in working order.

The French government adopted practically the same plan as the German, paying heavy premiums to truck purchasers on condition that the machines were to revert to the army for immediate use in case of war. The truck must be constructed entirely in France and in a factory where three-fifths of the labor is French. It must be in commercial use on French territory, and must conform in construction and equipment with the specifications laid down by the French military experts. Upon complying with the regulations, the truck owner receives a bounty ranging from $1022 to $1872. Each year all these trucks must be submitted to the military authorities and an exhaustive examination made to determine whether they fulfill all of the government requirements.

British Subsidy. The British government took up the matter of a truck subsidy in 1912, and went into the matter of mechanical detail to a much greater length than had either of the other great powers. The object has been to standardize the machines as far as possible, in order to make the manipulation and control of all the vehicles the same and to minimize the number of spare parts required. In brief, these specifications are as follows: A four-cylinder engine with the cylinders cast in pairs; valve mechanism entirely enclosed; large inspection doors on crankcase for access to motor bearings; except where ball bearings are employed on the crankshafts, lower half of crankcase must be detachable without disturbing main bearings; governors must be fitted and adjusted to limit engine speed to 1000 r.p.m.; ignition by high-tension magneto and a spare magneto must be carried; rods, not wire or cables, are specified for all engine controls; radiators must be carried clear of the frame on trunnions at the lower end, while the areas of the water passages have been standardized and are large enough to insure a thermo-siphon circulation; lubrication must be by a positively driven pump, and the system must have sufficient capacity to run the truck with a load for 200 miles without replenishing.

A four-speed transmission (gear box) and final drive by propeller shaft to a bevel-type live rear axle constitute the approved features of this essential, both chain and worm drive apparently being barred. Selective operation of the gear box with a safety catch on the reverse is required, and the driving effort is not to be taken on the rear springs, but by a combined radius rod and torque member universally jointed at the front end, while the propeller shaft must be enclosed. The rear axle must have a minimum clearance of 12 inches on new tires and a greater amount is preferable. The steering gear must be so arranged as to give 38 degrees of movement on either side of the longitudinal axis. Even the position of the control pedals and hand levers is specified. Curiously enough, roller bearings are barred and only certain standard sizes of ball bearings are to be carried in the field. Four towing hooks, two at each end, must be attached to the frame.

The fuel tank must hold 30 gallons, while the sizes of plugs, valve caps, screens, position of supply opening and feed pipe, as well as the diameter and length of the tank, are all standardized. At the intake, a screen must be provided in addition to that in the supply system, and means must be provided for cleaning out the tank. All grease cups are standardized. Two classes of trucks are specified, the smaller of 1½ tons' capacity (nominal) and the larger of 3 tons. The minimum wheelbase allowed for the latter is 13 feet, and for the smaller machines, 10 feet, while the platform area must be not less than 12 feet by 6 feet in the first case, and 9 by 5 feet 6 inches in the smaller trucks. The front seat must not only be wide enough to carry the driver, but two men on his left in addition. Two types of bodies are permitted, one with detachable sides not less than 2 feet high and provided with a frame for a canvas

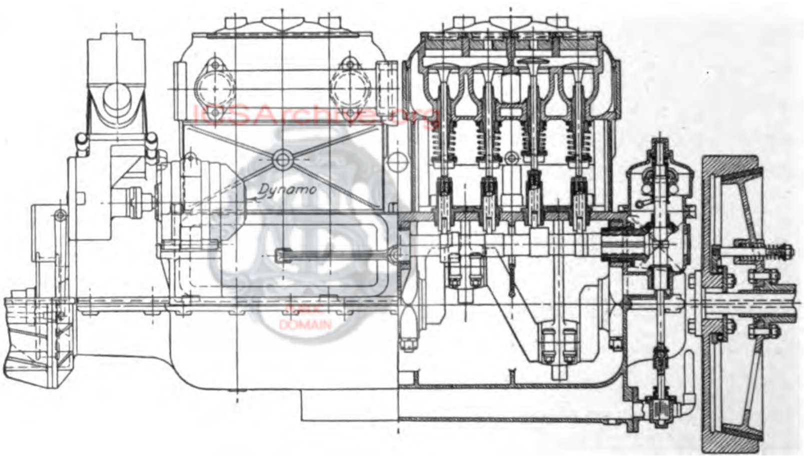


Fig. 356. Pagefield 3-Ton "Subsidy Model" Motor

cover, and the other of the box or "van" type, the former being in the majority. If the body employed by the owner does not comply with the specifications, a spare body that does must be purchased and kept in readiness. All bodies must be interchangeable.

The subsidy consists of a premium of $250, and if the chassis be fitted with a type of body of approved pattern for the carriage of meat slung from the roof, this is increased to $300. In addition, there is an annual payment of $100 per machine, all payments to be made half-yearly in arrear, so that the first installment is handed over six months after the acceptance of the truck. Thus in three years the owner of a subsidized truck would receive $600 if his truck were of the meat-carrying type, and $550 in the case of others.

In return for this subsidy, the war department has the right to purchase the machine, in case of war, at a price arrived at by deducting $7\frac{1}{2}$ per cent from the original cost for each half-year or part of a half-year that has elapsed since the delivery of the truck by the manufacturer, and then adding 25 per cent to the figure thus obtained; but if this figure exceed the original cost, then only the latter is paid. For example, if a $1000 truck were purchased within six months from date of delivery, depreciation would amount to $75, leaving $925, to which 25 per cent would be added, making a total of $1156.25; but, as this exceeds the original cost, only $1000 would be paid. If the truck had been in service three years, the depreciation would amount to 45 per cent, leaving only $550, plus 25 per cent, making the selling price $687.50 at the end of three years.

All subsidized cars are subject to a half-yearly inspection, loaded either in the garage or on the road; but, as the

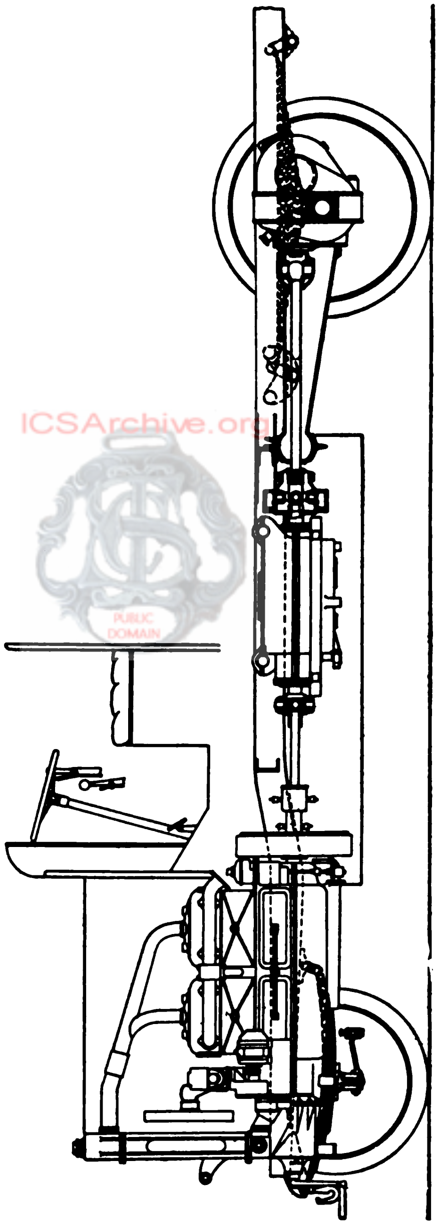


Fig. 357. Standard 3-Ton Truck Specified by British War Department

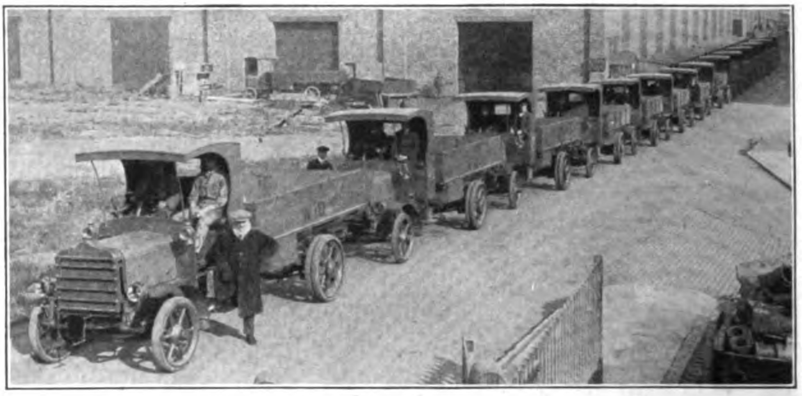


Fig. 358. Daimler Subsidy Trucks Ready for Delivery to British Army

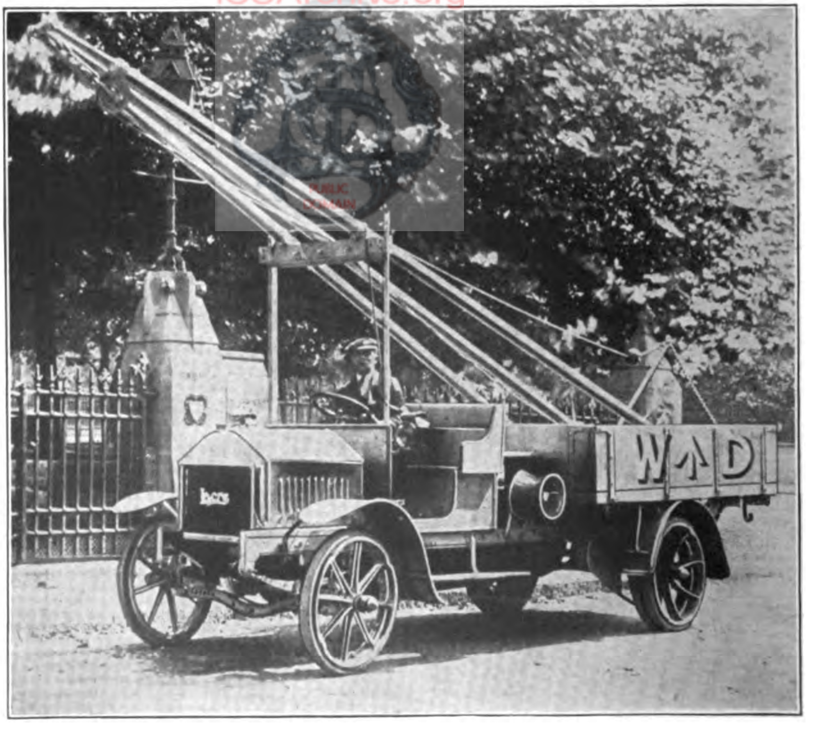


Fig. 359. Lacre Truck Fitted with Wireless Mast

inspection is made during the routine service of the machine, no reimbursement is made for time lost. If a car does not meet the requirements, the owner must put it in satisfactory condition before further payments are made. If it fails to pass more than one inspection, it may be dropped from the lists and all further payments cancelled. The system is not confined to owners, but is extended to manufacturers as well, while a "special reserve" has been organized for motor drivers, each man who joins receiving an annual retainer of $20. Fig. 356 shows the motor details of a typical British "subsidy model",

Fig. 360. British Napier Truck Supplied Russian Army

while Fig. 357 is the complete chassis, the car shown being the Pagefield 3-ton type. It will be noted that an electric-lighting dynamo is fitted, but no provision is made for self-starting. The details of the oil pump and governor will be seen at the right-hand end of the motor, which is partly sectioned to show them. In the photograph, Fig. 358, is shown a whole line of Daimler war department subsidy cars which have been approved and are ready for delivery. The Lacre truck, shown in Fig. 359, is intended for service with the signal corps and is fitted with a wireless mast for a field station. The head or winding drum of a hauling winch will be noted just back of the driver's seat. The use of these winches is a very general feature on the French military trucks, and particularly on the four-wheel-drive tractors, as the latter must be capable of hauling the trailers up hills and out of gullies by a steel cable when unable to drag them over the same ground with the tractor running. Of course, all the other European powers, such as Austria, Italy, and Russia, have also put subsidy schemes into force, Fig. 360, showing a British Napier 3-ton truck supplied to the Russian government for military use. In Fig. 361 is shown one of the methods employed by the French army for testing trucks for military use before approving them. Both of the machines shown are four-wheel-drive tractors.

Fig. 361. Method of Testing Motor Trucks for Military Use in French Army
Courtesy of Automobile Topics, New York City

They are hitched to a heavily loaded trailer placed in the bed of a creek and compete with one another in a novel form of "tug-of-war". The tractor that succeeds in hauling the trailer out of the creek bed, and with it the competing machine, is declared the victor.

MOTORCARS IN ACTION

Variety of Service. There is no form of military service to which motor trucks have not been put in the great European campaigns, including that of actual fighting, hundreds of them having been converted into miniature traveling forts, as in Fig. 362. Others are fitted out as traveling field kitchens and are attended by whole lines of provision wagons. They haul the guns and ammunition, as shown by Fig. 363, which illustrates a French tractor pulling a field gun and a trailer with ammunition. They transport the aeroplanes from one part of the field to another, a specially adapted body

Fig. 362. Sava Armored Car with Belgian Army, Battle of Yser
Courtesy of The Commercial Vehicle, New York City

Fig. 363. Motor Truck Hauling French Field Artillery
Courtesy of Automobile Topics, New York City

being provided to receive the flyer, without its wings, as shown, by Fig. 364. Others provide both the power and the traveling plat-

form for the huge searchlights which have made night fighting such a prominent feature of the battles. One of these machines is shown

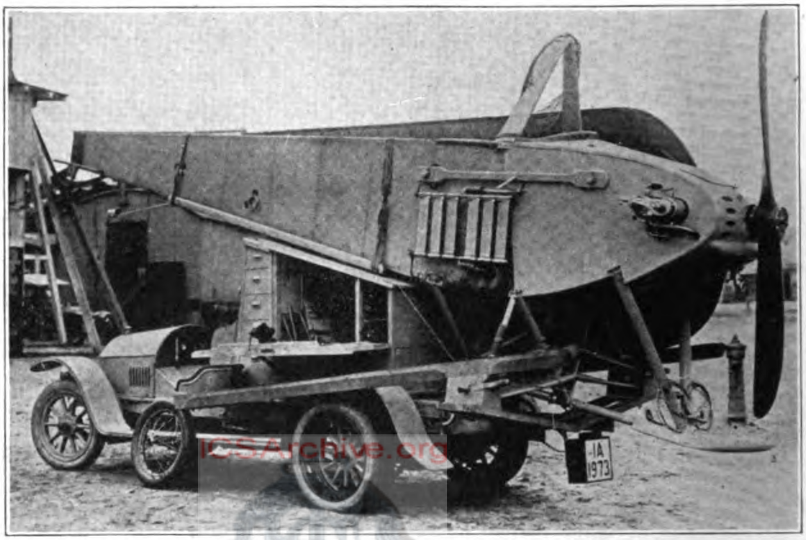


Fig. 364. How Aeroplanes Are Transported by French Army
Courtesy of Automobile Topics, New York City

in action in Fig. 365, while a similar searchlight car armed with a rapid-fire gun and manned by British soldiers is shown in Fig. 366.

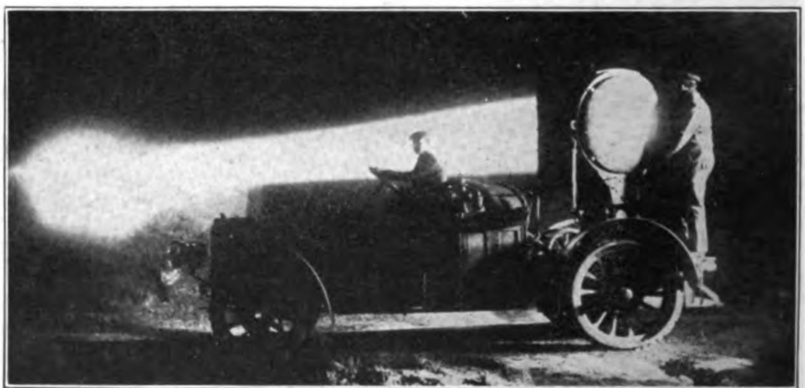


Fig. 365. British Army Searchlight Mounted on Motor Truck
Courtesy of Automobile Topics, New York City

Last, but far from least, there are the thousands of ambulances, many of which, of course, are simply converted cars. Fig. 367

shows a specially designed British Daimler pneumatic-tired ambulance, the interior equipment of the body being illustrated by Fig. 368.

Fig. 366. Searchlight and Rapid-Firing Gun on a British Army Motor Car
Courtesy of Automobile Topics, New York City

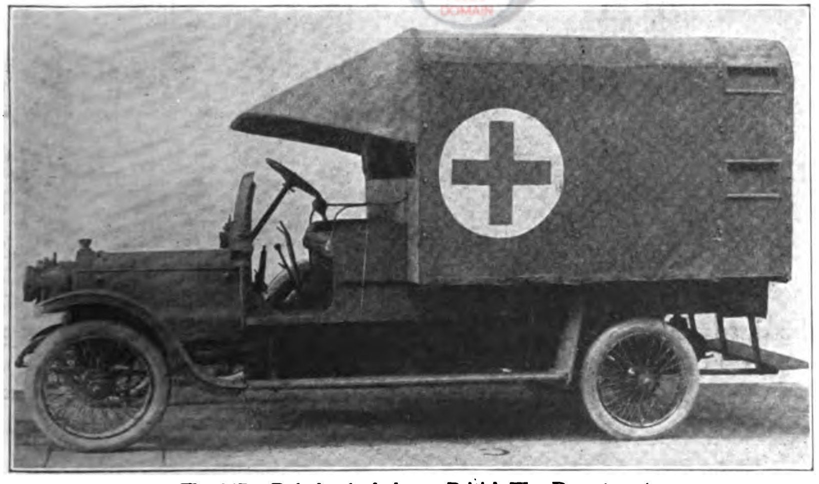


Fig. 367. Daimler Ambulance, British War Department

Insufficient Supply. At the outbreak of hostilities each one of the governments in question, not only called for all subsidized machines, but also commandeered practically everything that burned gasoline, from a motorcycle up. Entire lines of Paris busses suspended operation at an hour's notice, as all the cars were taken for military use. Many of the London busses were taken also. There were about 1500 each of German and French subsidized machines and probably not quite so many British trucks called for at the start; but, as they fell far short of meeting the requirements, almost everything available in the form of a motor truck was uti-

Fig. 368. Body of Daimler British Army Ambulance

lized, so that before the war had been under way a month there were about 30,000 ex-commercial vehicles either at the front or acting as feeders to the troops engaged. Chief among the motor vehicles not on the actual battle line are the provision transports, ammunition trucks, and the motor ambulances. The German ammunition trucks are fitted with a powerful hoisting drum and a steel cable tested to a breaking strength of 1000 metric tons. The tractor motor itself develops 100 horsepower and could easily haul an ordinary freight train on the level. Several of these big tractors were responsible for the rapidity with which the German 42-centimeter (16½-inch) siege guns were brought up.

Notwithstanding the elaborate plans made and the great number of vehicles commandeered, a shortage made itself felt at a very early date and, as none of the belligerent nations was in a position to manufacture trucks as fast as they could be destroyed, thousands of American-made machines have been participating in the campaigns. The life of a motor truck in military service is indeed of brief duration. If it be employed for the transportation of ammunition, so that the service rendered involves its actually being at

Fig. 369. Fate of an Ammunition Train, Battle of the Marne
Courtesy of Automobile Topics, New York City

the front, its fate is apt to be that shown by Fig. 369. A few hours before the picture was taken, the piles of debris seen at the roadside represented a motor ammunition train of 15 to 20 cars, valued probably at $50,000 to $60,000 exclusive of the thousands of dollars worth of shells they were carrying. The train was ambushed by the enemy and the trucks and their contents burned. The picture shows only a small part of the wreckage, which extended along the road in the other direction for several hundred yards.

Broad Lines of Transport Organization. The partial transition from horse to motor transport has brought about considerable modifications in military transport, a good example of which is afforded by the methods in use in the British army. Under the old classification, transport was divided into three main branches; first-, second-, and third-line transport, as follows:

First-Line Transport. (*a*) Carts and wagons for rifle and machine-gun ammunition, pack mules for rifle ammunition and tools, animals for machine guns, carts for tools and medical stores; (*b*) technical transport for artillery and engineers, and the ambulances and water carts of the medical corps.

Second-Line Transport. (*a*) The vehicles and animals conveying the stores, baggage, and regimental supplies of all units of the fighting troops, and regimental water carts, i.e., carrying all equipment not needed in action; (*b*) artillery ammunition columns, carrying reserves of rifles as well as gun ammunition, and moving immedi-

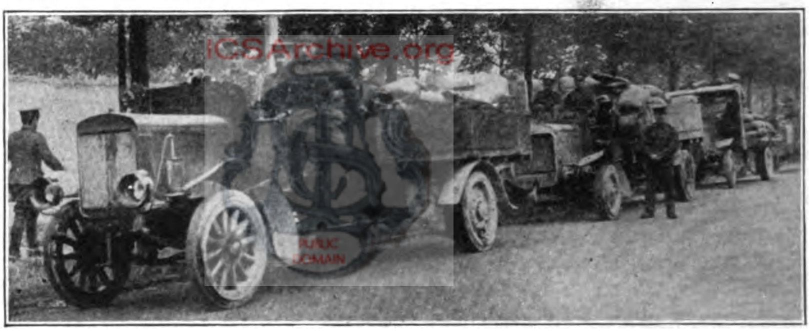


Fig. 370. A British Army Provision Train on the Way to the Front
Courtesy of The Commercial Vehicle, New York City

ately in the rear of the troops—in other words, at the head of the second line; (*c*) wagons of the transport and supply columns.

Third-Line Transport. Ammunition and supply packs, maintaining connection between advanced depots or railhead and the advanced columns.

With the increasing use of the automobile, the motor trucks run direct from the advanced bases or railhead to within five miles of the front, if possible, at which point they supply the ammunition columns and the regimental supply wagons of the old second line. With horse transport, fifty-four service wagons were allotted to each division, and each of these was capable of carrying 3000 pounds. This number of wagons and teams has been easily replaced by twenty-four trucks of the same capacity. Fig. 370 shows a British motor supply train. But the value of the automobile has not been confined to supply transport, as large numbers have been employed in fighting, both the Germans and the Allies having a great many armored cars. One of the difficulties arising in their use has been the necessity for turning around in narrow roads under fire, and it is quite possible that, as the result of this, cars will be developed which will run equally well in either direction without any sacrifice of steering efficiency.

Motor Artillery. One branch in which the automobile truck has been of the greatest importance is the transport of artillery and the hauling of heavy guns, in which the Germans have excelled. It requires a team of thirty horses or more to haul the 11- and 16½-inch guns and, in addition to being extremely difficult to handle, the animals are likely to stampede. The larger of these guns, each firing a 750-pound shell and weighing complete 13½ tons, were drawn by motor tractors. To provide sufficient bearing surface for such a weight, the wheels of the guns are fitted with large square hinged pads which spread the load over several times the area that would be possible with the widest tire practicable, the principle being that employed in the "Pedrail" tractor.

Under the old line organization, infantry marched and cavalry rode, but the automobile has changed this as well, so that the infantryman now goes to the fighting line in a taxicab when his services are required in a hurry. Thousands of taxicabs have been drafted from the streets of Paris and London, though more particularly the former, and an instance is recorded in which a detachment bridged a ten-mile gap at high speed with the aid of 1500 taxicabs. Napoleon would certainly have to revise his idea of mobility under present conditions.

Multitude of Uses. Just as there is nothing in commercial transport work which the motor truck cannot do better and faster than the horse, so his place is taken in every phase of military necessity by the gasoline-driven machine. Everything the soldier eats, wears, or uses, and the letters he receives from home, as well, come at least a part of the way by motor truck. Indeed, the French military postal service is said to have been brought to such a degree of efficiency that a letter posted in New York will be delivered at the fighting line three weeks later. In addition to caring for the wants of the men at the front, the motor truck likewise provides for its own needs by hauling fuel in far lighter and more powerful form than feed for horses can be transported. With horse transport a very substantial percentage of the wagons did nothing but haul grain and hay for the animals. Among the many special uses to which the motor truck has been put is that of the traveling repair shop, as shown by Fig. 371, the transport and operation of a water-distilling plant, motor kitchens, and the like.

In addition, the automobile has emphasized its greater safety from capture as compared with horses, to say nothing of its freedom

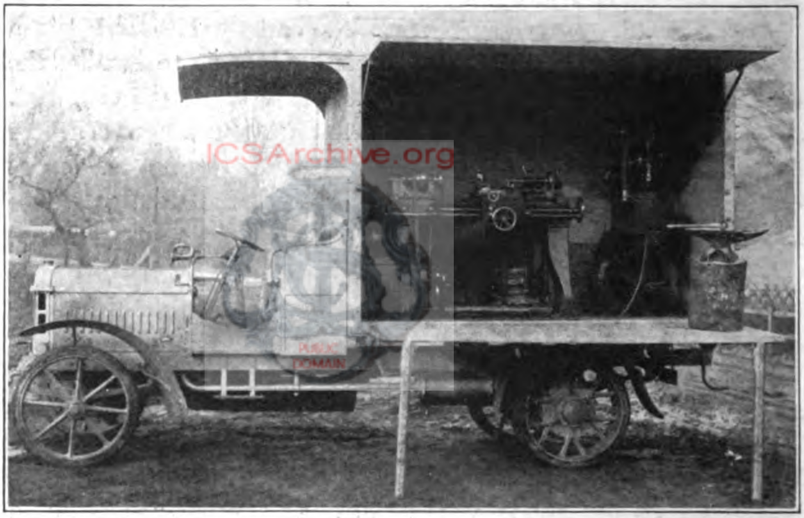


Fig. 371. British Army Motor Repair Shop on a Dennis Truck
Courtesy of The Commercial Vehicle, New York City

from the dangers of stampede. Not that the motor truck is by any means entirely free from breakdown or destruction, as hundreds of the vehicles employed by both sides have suffered from one or the other of these causes, although in any case the accident could hardly be regarded as due intrinsically to the form of transport. The most frequent troubles have been with the radiators, the breaking of springs, and the working loose of bolts, this being particularly true of those cars not designed for the Belgian roads. Naturally hundreds of trucks have had to be abandoned at various stages, but had horse transport been employed exclusively, breakdowns and abandonments would have been far greater in number and even in total load capacity and value. The work is not only the most severe to which automobiles have ever been subjected, but the machines often

Fig. 372. Pierce-Arrow Truck for French Service

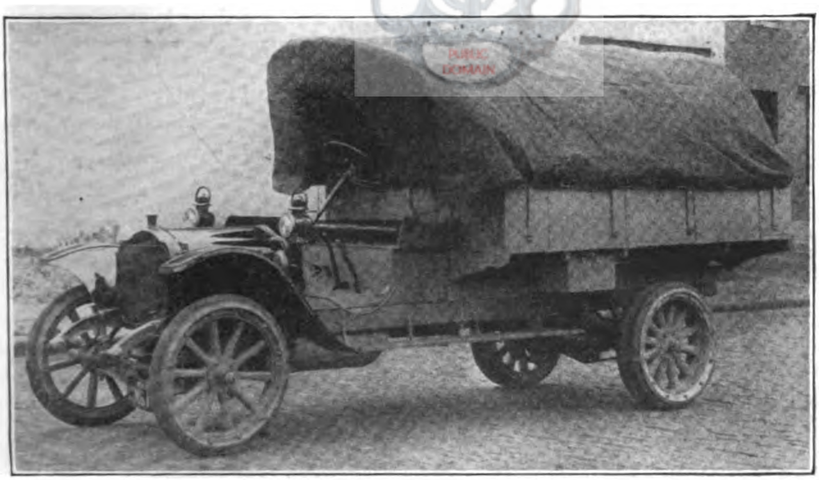


Fig. 373. White 3000-Pound Truck for British War Service
Courtesy of The Commercial Vehicle, New York City

have to be driven at savage speeds by inexperienced men. Add to this, the liability to destruction by shell-fire or capture, and the statement which has become current that the average life of a motor truck employed at the front scarcely exceeds more than six days, and for general transport thirty days does not appear at all overdrawn.

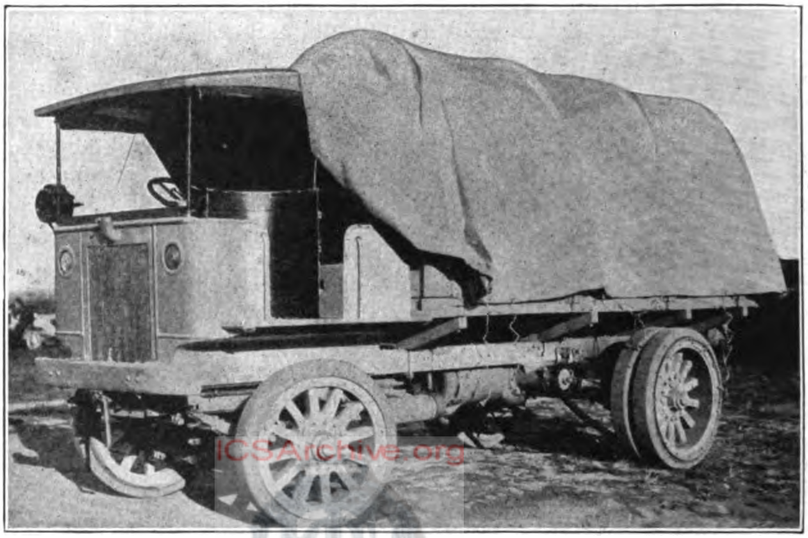


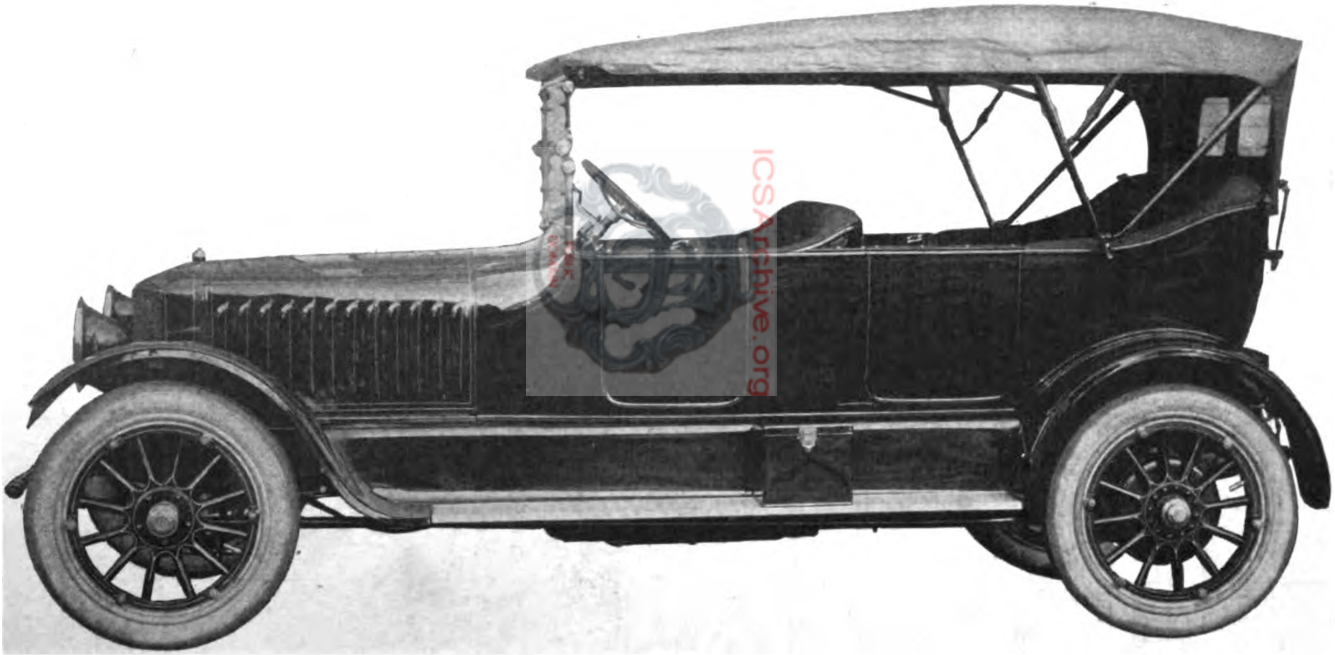
Fig. 374. Garford Truck Equipped for European War Service
Courtesy of The Commercial Vehicle, New York City

Fig. 375. Jeffery "Quad" in Active Service on Mexican Border, during U. S. Government Test

Where the actual movement of large bodies of infantry is concerned, the advent of the motor truck in warfare has brought about a complete reversal of practice. Hitherto, the speed of an army was limited by its transport, but with motor supply trains, that limitation has disappeared, as the transport can now out-travel the army. This is said to have been responsible for keeping men on the march past the point of utter exhaustion, as occurred with some of the German troops in their rapid dash through northern France.

American Trucks at the Front. As New York City alone, according to the official census, had at the end of 1913 more commercial vehicles in daily use than were employed in the whole German Empire and slightly more than 50 per cent as many as were in use in England at the same time, the number available for use in the war fell far short of the requirements. This, coupled with the extremely rapid destruction of those pressed into service, led the allied forces to look to the United States for new supplies. As a result, more American commercial vehicles were exported from this country in one month than had ever been sent abroad previously in an entire year, the valuation of the exports for the thirty days in question exceeding two and a quarter million dollars. Figs. 372 to 374, inclusive, show how the standard machines were adapted for military work.

United States Army Subsidy. The question has been seriously raised as to whether the United States Army should not adopt the subsidy system now in force abroad, or something calculated to achieve the same end, in order that proper transports might be available in case of emergency. It is estimated that for an army of 2,000,000 men, such as Germany put in the field within thirty days, no less than 90,000 ordinary wagons would be required. For these and the ambulances, some 360,000 horses or mules would be necessary, and these animals with their vehicles would need 720 miles of road space. They would eat over 5,000,000 pounds of hay and 3,250,000 pounds of grain a day at a daily cost of about $83,000. While no official steps have been taken toward this end up to the present writing, American army officers have drawn up specifications for a type of truck that would be capable of traveling "anywhere a four-mule team would go". The truck built in accordance with these specifications is the Jeffery "Quad", or four-wheel-drive, described in the section on that type of transmission. One of these trucks in military service is shown in Fig. 375.



SIDE VIEW OF STANLEY STEAM TOURING CAR
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

STEAM AUTOMOBILES

INTRODUCTION

Development of Steam Engines. That steam could be employed to produce mechanical motion was first noted in history about 130 B. C., but it was not until the seventeenth century that it found practical application in the industries. The developments were comparatively slow, however, until James Watt (1769) developed his engines to a point where they employed practically all the principles of the modern double-acting, condensing steam engine.

With these rapid inprovements came the idea of using the steam engine as a means of road locomotion, and in the opening years of the

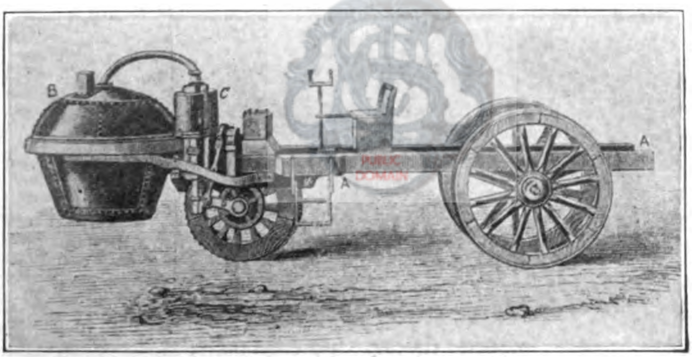


Fig. 1. Early Steam Carriage Built by Cugnot (France) in 1770

nineteenth century such machines were actually built and known as "road locomotives", Fig. 1. These machines might be called the forerunners of the steam automobile, although structurally they more nearly resembled the later traction engines. Bad roads, great weight, public opinion, and the development of railroads caused road locomotives to drop out of sight until the real coming of the automobile almost a hundred years later.

In the meantime the steam engine—both stationary and locomotive types—had reached a high state of development and hence many of the early automobiles carried this type of power plant.

Later improvements were made and are still being made along lines peculiar to steam automobile construction. Although during the last few years the steam car has not kept pace in numbers with other types of automobiles, it has certain characteristics, such as strong pulling powers at low speeds, capacity for big overloads, and ease in driving on the road, which make it especially useful under some conditions, the success of the London steam omnibuses being a good example.

CHARACTERISTIC FEATURES OF STEAM CARS

In the modern steam automobile the power plant is made up of the same general units as make up the stationary power plant, the only difference being the extreme compactness necessary and the development of the great flexibility required to meet the sudden changes in load conditions. With both plants there must be a supply of fuel, a means of burning it, a boiler or steam generator, a supply of water, an engine, and various means of controlling the amounts of fuel, water, and steam.

Location of Engine. With steam automobiles there is no uniformity of practice as to the placing of the different units in the

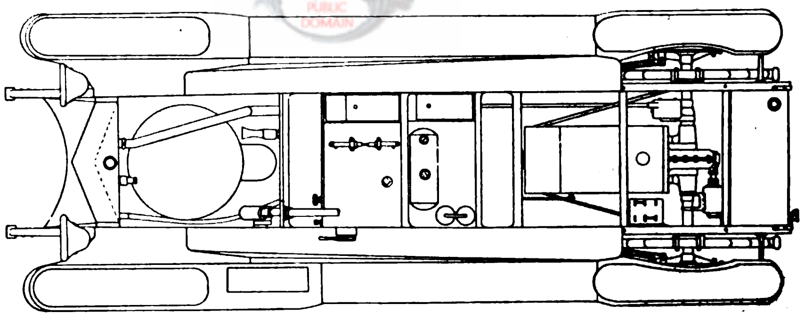


Fig. 2. Plan View of Stanley Steam-Car Chassis
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

running gear or chassis. For instance in the Stanley, Fig. 2, the boiler is under a hood in front of the driver and the engine is geared directly to the rear axle. In the case of the White cars, Fig. 3, which were built in comparatively large quantities from 1904 to 1910, the engine was placed under the hood in front with a shaft running back to the rear axle. In the White car, a set of gears was also used in the drive, by which the relation of engine to wheel speed could be reduced to one-half the usual amount, thus doubling the driving effort, or "torque". The White boiler was under the front seat. The new Doble, Fig. 4, uses the same general arrangement as Stanley. In the

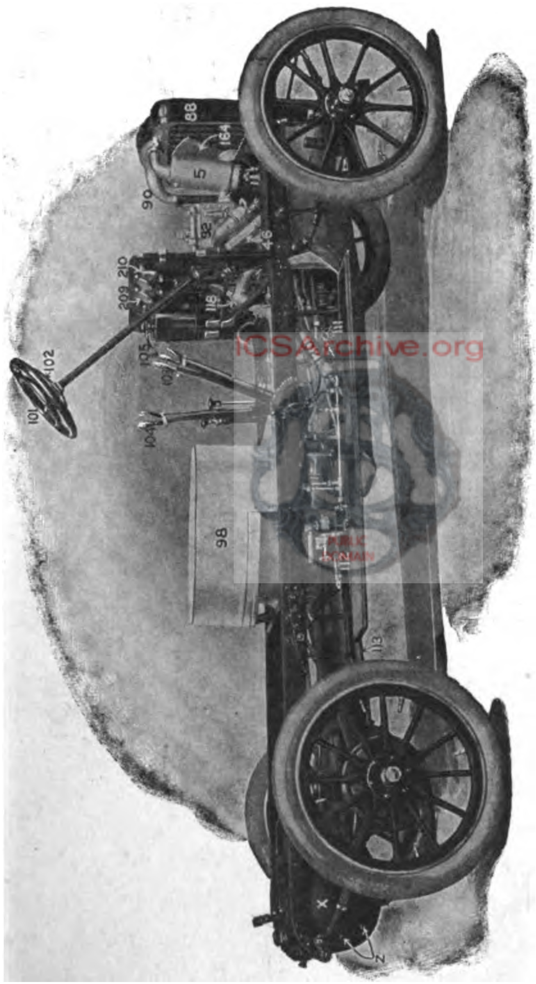


Fig. 3. Side View of White Steam-Car Chassis
Formerly Manufactured by The White Company, Cleveland, Ohio

Leyland steam truck, Fig. 5, and the National busses, both of England, the boilers are in front, the engines are under the floor boards, with a countershaft and final chain drive, as in Fig. 5, or a shaft drive direct to the rear axle.

Boiler and Engine Types. Almost equal variation is found in the types of boilers and engines. The difference between fire-tube,

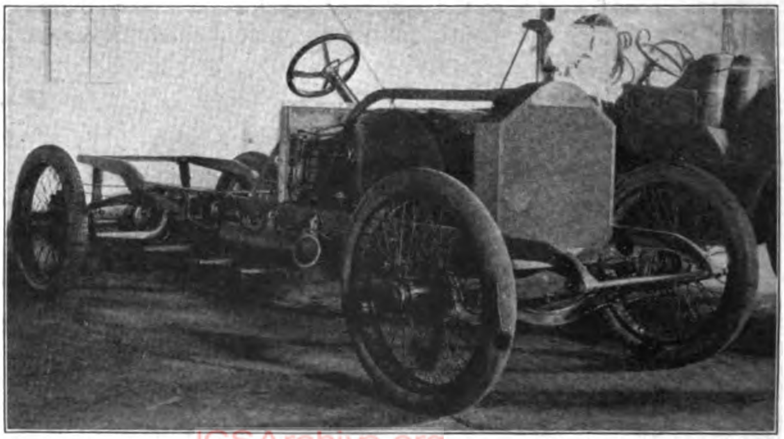


Fig. 4. Side View of Doble Steam-Car Chassis
Courtesy of Abner Doble, Waltham, Massachusetts

water-tube, and flash generators is taken up in the section devoted to boilers, while the engine types are taken up in their respective section.

Fig. 5. Leyland Steam-Driven Truck with Chain Final Drive
Courtesy of Leyland Motors Company, Ltd., England

Some of the cars use the water over several times by condensing the steam in coolers, or "condensers", placed at the front of the car. The

White and Lane did this, and it is now done by the Doble and most of the English steam cars and trucks. The Stanley has no condenser, allowing the steam to escape into the air after it has passed through the feed-water heater.

Simplicity of Control. With the exception of the low-speed gear employed on the White, which has been mentioned, steam cars do not employ a transmission for giving various forward-gear ratios and a reverse. The extra heavy loads, as in starting, are taken care of by lengthening the cut-off and by "simpling", terms which will be more fully explained later. Instead of running the engine always in one direction and using a gearset for reversing the car, as is done on gasoline automobiles, the engine is itself reversed by means of changing the timing of the valves through the valve gear, or linkage.

This change of the valve-timing is used only at starting, reversing, or under very heavy load conditions, all ordinary running being accomplished with the cut-off in one position. The control of the speed of the car, therefore, is accomplished under normal conditions by changing the amount of steam going to the engine. The steam is turned on or shut off by a hand-operated valve, known as the "throttle valve", and this valve is turned by a lever, or second small wheel, just above or below the steering wheel. Thus the actual driving of a steam car consists of steering and operating the throttle. There are, however, numerous gages, valves, etc., which have to be worked upon when firing up, and which have to be given occasional attention on the road; these will be considered in detail in the following pages.

Having treated in a general way the different types of steam cars and their parts, the theory underlying the behavior of steam will be touched upon before taking up the details of construction and the operation of the various units.

HEAT AND WORK

HEAT TRANSMISSION

All forms of energy, such as light, sound, electricity, and heat, are believed to be different forms of vibration either of the molecules of material substances or of the ether which is believed to pervade all space.

Energy is indestructible, but any form of energy may be converted into any other form. Steam engines are classed as heat engines since they are employed to transform heat energy into mechanical work. Heat may be transmitted from one body to another in three ways, namely, by radiation and absorption, by conduction, and by convection.

Radiation and Absorption. Radiation is the transfer of heat from one body to another body not in contact with it. It takes place equally well in air or *in vacuo*. The rate of heat transferred depends partly on the distance separating the two bodies, and partly on the nature of their surfaces. In general, light-colored and polished metal surfaces radiate heat more slowly than rough and dark-colored surfaces. The laws governing absorption are the same as those governing radiation.

Conduction. Conduction is the transfer of heat through the substance of a body—solid or liquid—to other portions of the same body, or to another body in physical contact therewith. Metals are the best conductors of heat, but some metals, such as copper, are better conductors than others. Other solids, such as stone, wood, etc., rank after the metals. Liquids are very poor, and gases still poorer, conductors of heat. A vacuum is perfectly non-conducting, though radiation may still take place through it.

Convection. Convection is the term applied to the absorption of heat by moving liquids or gases in contact with heated surfaces. If a blast of air be directed on a piece of hot iron, the iron cools far more rapidly than it would in still air. The reason is that, as the air is a poor conductor, its molecules do not transmit heat readily from one to the next, but if each molecule on becoming heated is immediately replaced, heat is rapidly transferred. This property of air of taking up heat rapidly when blown over a hot surface is employed in gasoline automobiles to cool the so-called "radiators". In reality, the heat radiated cuts a small figure compared with that dispersed by convection.

What has just been said regarding air is equally true of other gases. It is also true of most liquids.

Relative Conductivity. Heat conducting qualities vary for different substances. Silver, copper, and aluminum conduct heat very rapidly, while asbestos is a poor heat conductor and is therefore used around the outside of automobile boilers.

Expansion. Another heat property which has to be considered in the selection of material for steam cars is that of expansion. Some metals expand much more than others for each degree of rise in temperature. Since brass and copper both expand under heat much more than iron they are used in preference to iron in the construction of expansion tubes, which are fully described later.

Temperature Measurement Scales. Temperature, which is the measure of the intensity of heat, is expressed by means of divisions called *degrees* on some thermometer scales. The two thermometers in most general use are the Fahrenheit and Centigrade; the former being the more common in America and England for both engineering and household use, while the latter is used exclusively on the Continent.

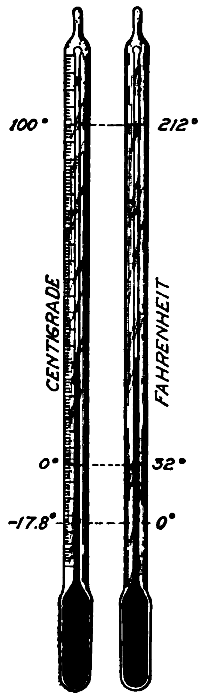


Fig. 6. Centigrade and Fahrenheit Thermometers, Showing Comparison

Freezing of water occurs at 32° F. (Fahrenheit) and boiling of water at 212° F. The scale between these two points is divided into 180 equal parts. On the Centigrade scale, the points of freezing and boiling occur, respectively, at 0° C. and 100° C., and there are, therefore, 100 equal divisions between the two points, Fig. 6. Thus it is seen that every 5 degrees Centigrade equal 9 degrees Fahrenheit.

Conversion of Scales. To convert readings in one scale to readings in the other, the reading given is substituted in the following equation:

$$\frac{°F-32}{180}=\frac{°C.}{100}$$

Thus, if a temperature is given as −5° C. it is equal to 23° F.; 23° C. equals 73.4° F. Conversion tables over large ranges are given in engineering handbooks, such as Kent.

Absolute Zero. In engineering calculations the absolute zero and the absolute scale are sometimes spoken of. This absolute zero, which will be mentioned again, is taken as −270° on the Centigrade scale and −460.6° on the Fahrenheit scale. Thus −5° C. equals +265° on the C.-absolute scale and +483.6° on the F.-aboslute scale.

LAWS OF GASES

Almost all substances expand with rise of temperature. Solids expand least, and in some the expansion is imperceptible. Liquids expand about as much as solids, sometimes slightly more. Gases and vapors expand a great deal if free to do so.

Boyle's Law. Before considering the expansion of gases under changes in temperature, let us see how they act when the temperature is unchanged. A gas is perfectly elastic, that is, if not confined in any way it would expand indefinitely. The attraction of gravity is all that prevents the atmosphere surrounding the globe from dispersing into infinite space. When air is partly exhausted from a closed vessel, the remainder, no matter how small, expands so as to distribute itself equally throughout the vessel.

If a cubic foot of air at atmospheric pressure be compressed into one-half cubic foot without change in temperature, its pressure will be precisely twice what it was before. In speaking of gas pressures in this manner, it is customary to deal with absolute pressures, that is, pressures above a perfect vacuum. Thus atmospheric pressure at sea level is approximately 14.7 pounds per square inch, and a cubic foot of air reduced one-half in volume will have an absolute pressure of 29.4 pounds.

This relation of pressure and volume is expressed in "Boyle's Law", which states that, so long as the temperature is unchanged, the product of the pressure and volume of a given weight of gas is constant. That is

$$P\,V = C$$

This is the most important of all the laws of gases.

Curve Expressing Boyle's Law Relation. Fig. 7 expresses the relation between volume and pressure of a given weight of air starting at atmospheric pressure and compressed to a pressure of 500 pounds without change in temperature; also expanded to a pressure of one pound absolute. Horizontal distances represent volumes, the volume at atmospheric pressure being unity; and vertical distances represent absolute pressures. To find the pressure of the air for any volume greater or less than one, locate the given volume on the base line, then, from this point, read up to the curve and find the desired pressure by moving horizontally from the curve to the scale at the left.

Behavior of Gases with Changes of Temperature. As heat is a mode of motion, it follows that when all heat is withdrawn motion ceases, and the molecules, even of a gas, become fixed. From experiments and theoretical considerations the absolute zero, representing the absence of all heat, is believed to be −273° C., or approximately −460° F. In most theoretical studies of the behavior of gases, temperatures are reckoned from absolute zero instead of from the arbitrary zeroes of the conventional thermometer.

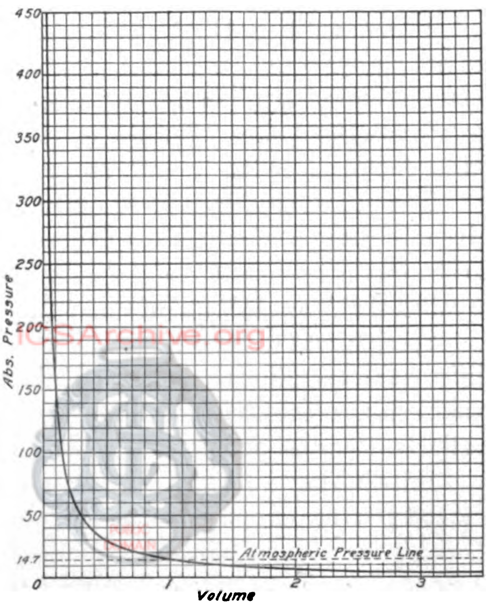


Fig. 7. Curve Showing Relation between Volume and Pressure of Air

When a gas of given weight at an absolute temperature of 273 degrees—that is, 0° C. on the customary scale—is raised in temperature one degree without change in pressure, its volume is increased $\frac{1}{273}$. A second degree of added temperature increases its volume the same amount, and so on. In other words, for each degree Centigrade of added temperature its volume is increased $\frac{1}{273}$ of its volume at 273° A.

If degrees Fahrenheit are taken instead of Centigrade, the expansion is $\frac{1}{491}$ of the volume at 32° F. for each degree of rise in temperature. Five degrees C. equal nine degrees F.

If the gas thus heated is so confined that it cannot expand, it will suffer an increase in pressure in the same proportion, that is, $\frac{1}{273}$ of its pressure at 0° C. for each degree Centigrade. If the gas, instead of being heated, is cooled, its shrinkage in the one case or its loss of pressure in the other will follow the same rule as above. Theoretically it follows that at −237° C.—absolute zero—the gas would have no volume at all. Of course that is impossible, but at ordinary temperatures the gases behave as if the assumption were true.

HEAT TRANSFORMATION

Specific Heat. The temperature of a body and the heat it contains are two different things. A gallon of water at 100° F. contains twice as much heat as half a gallon at the same temperature. That is to say, twice as much heat was imparted to it in raising it to that temperature.

Like quantities of different substances at the same temperature do not always contain the same quantity of heat. A pound of water contains more heat than a pound of oil or alcohol at the same temperature. It requires 7.7 times as much heat to raise a pound of water one degree in temperature as a pound of cast iron.

The quantity of heat required to change the temperature of a given weight of a substance one degree, compared with that required to change the temperature of the same weight of water a like amount, is called the "specific heat" of that substance.

Specific heat varies considerably for different substances, and for different temperatures and states of the same substance. Thus the specific heat of steam is much less than for water and varies slightly as the temperature and pressure of the steam is varied.

British Thermal Unit. The quantity of heat required to raise the temperature of one pound of water one degree F. is known as the "British thermal unit" (B.t.u.). Another unit is the "calorie", which is the quantity of heat required to raise the temperature of one kilogram (2.2046 lb.) of water one degree Centigrade. One calorie equals 3.968 B.t.u. The B.t.u. is the unit generally used in this country for engineering calculations. The latest investigations lead to slightly different and more complicated definitions of the B.t.u. from the one given above, but this is near enough for practical calculations.

Heat Value of Fuels. The number of heat units liberated by burning a pound of fuel varies for different fuels. The *heat value* for fuels is determined by experiment, and by calculation when the chemical composition is known. Due to the variation in the composition of commercial gasoline, different samples will give different results, but for most calculations the figure of 19,000 B.t.u. Kerosene has a slightly higher value.

Force. Force is defined as that which produces, or tends to produce, motion, and in practical work is usually expressed in units of weight, for example, pounds, kilograms, or tons. A force may exist without any resulting motion, and therefore without work being done. For example, the weight of any object represents the force of gravity attraction between the earth and that body. The atmosphere exerts a pressure or force of approximately 14.7 pounds per square inch at sea level.

Work. Work is done when force is exerted by or on a moving body, and is measured by the product of the force into the distance through which it is exerted. A convenient unit of work is the "foot-pound", which is the work done in lifting a weight of one pound against the force of gravitation a vertical distance of one foot, or exerting a force of one pound in any direction through a distance of one foot.

Power. Power expresses the rate at which work is done. If a foot-pound of work is performed in a minute, the power is small. If it is done in a second, the power is 60 times as great. The customary unit of power is the horsepower, which is 33,000 foot-pounds per minute. Whether a force of 33,000 pounds be exerted through one foot of distance, or one pound be exerted through 33,000 feet in the same time, the power is the same.

Mechanical Equivalent of Heat. Heat may be converted into work or work into heat. Experiments have been made in which water was agitated in a closed vessel by means of paddles run by falling weights and the resulting rise in temperature of the water carefully determined. From these and other experiments, it has been ascertained that one British thermal unit is the equivalent of 778 foot-pounds of work. That is, a weight of one pound falling 778 feet, or 778 pounds falling one foot, developed sufficient energy to raise one pound of water one degree F. in temperature. A horsepower, therefore, equals 42.416 B.t.u. per minute. The combustion of one pound of either gasoline or kerosene liberates approximately 19,900 B.t.u., but the kerosene is heavier for equal bulk. One U. S. gallon of gasoline weighs about 5.6 pounds; of kerosene, about 6.25 pounds. The combustion of a gallon of kerosene per hour develops theoretically about 49 horsepower but the actual amount of energy obtained falls far short of this. Owing to heat losses in the boiler and exhaust, and to radiation, etc., only a small fraction of this energy can be converted into useful work.

THERMODYNAMICS OF STEAM

Latent Heat. If water be heated in an open vessel it will reach a temperature of approximately 212° F. (100° C.) and will then boil away without further rise in temperature. The added heat is absorbed in converting the water into steam.

It takes far more heat to convert water into steam than to raise its temperature. A pound of water heated to boiling from 32° F. absorbs only 180 B.t.u., but in boiling away at 212° F. it absorbs 966 B.t.u. additional. At atmospheric pressure the volume of the steam is 1645 times the volume of the water whence it came. This bulk of steam must displace an equal bulk of air, and part of the heat energy represented by the steam has been spent in pushing back the air to give it room. This will be made clearer from the sketch, Fig. 8, showing a long tube open at the top and containing a little water at the bottom. On top of the water is a piston, supposed to be air-tight and without weight or friction. If the water be boiled into steam, the piston will be pushed upward against the atmospheric pressure a distance equal to 1645 times the original depth of the water. The work in foot-pounds thus done will be 14.7 times the area of the piston in square inches times the distance in feet through which it has moved. Approximately 7.45 per cent of the heat imparted to the steam represents work done against the atmosphere; the remainder is spent in overcoming the mutual attraction of the molecules of water. The heat which has been absorbed by the change in state from water to steam without change in temperature is called the "latent heat of vaporization".

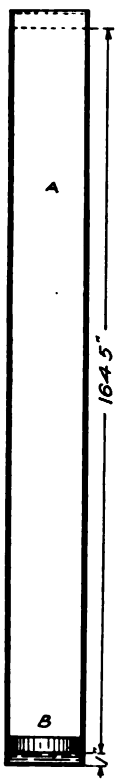


Fig. 8. Expansion of Water into Steam

If a vessel containing water at 212° F., which is the atmospheric boiling point, be put under the receiver of an air pump and the air partly exhausted, boiling will take place spontaneously without further addition of heat. At the same time the temperature of the water will decrease, because part of the heat contained in it has been absorbed by the conversion of water into vapor. If the air pump keeps on working, the water will boil continuously while its temperature steadily descends. If the experiment be carried far enough, with the vessel so supported that it can absorb little or no heat from adjacent objects, and if the vapor given off be rapidly absorbed, for example, by placing a tray of quick-lime or sulphuric acid adjacent, the water may actually be frozen by its own evaporation.

This experiment shows that the boiling point of water—and this includes other liquids also—is not a fixed temperature but depends on the pressure. All volatile liquids when exposed to partial or complete vacuum give off vapor; on the contrary, this vapor when subjected to pressure partly re-condenses and a higher temperature is needed to produce boiling. Under an absolute pressure of 147 pounds or 10 "atmospheres", the boiling point is 356.6° F. At 500 pounds absolute pressure the boiling point is 467.4° F. (242° C.).

The "total" heat of steam at the boiling point corresponding to a given pressure is the sum of its latent heat of vaporization and the heat contained at the same temperature in the water from which the steam was formed. The total heat of steam increases slowly, but the latent heat diminishes nearly in proportion as the boiling point rises. The space occupied by a given weight of steam diminishes approximately in proportion to the increase in pressure. In this respect the steam resembles a perfect gas without change of temperature in accordance with Boyle's Law. Tables showing the pressures, temperatures, latent heat, etc., of steam are given in Kent and other handbooks.

The experiment just cited of producing spontaneous boiling in water by exhausting the air above it, may be duplicated with hot water at any temperature and pressure. For example, the boiling point of water under 100 pounds absolute pressure is 327.6° F. If, in a boiler containing water at that temperature and pressure, the pressure be reduced to 50 pounds by the withdrawal of steam, the water will boil spontaneously, absorbing its own heat in doing so, until it reaches a temperature of 280.9° F., which is the boiling point for 50 pounds absolute pressure.

Cause of Boiler Explosions. Owing to the property of giving off steam under reduction of pressure, every steam boiler constitutes a reservoir of energy which may be drawn upon to carry the engine through a temporary period of overload. In other words, the boiler will give out steam faster than the fire generates steam, the difference being supplied from the heat stored in the water itself. This is an exceedingly useful feature of the ordinary steam boiler. At the same time, and for the same reason, it is a source of danger in case of rupture of the boiler shell. If a boiler explosion involved simply the release of the steam already formed it would not be so serious a matter; but when a seam starts to "go" the adjacent portions are unable to carry the abnormal strain put upon them, and the result is a rent of such proportions as to release almost instantly the entire contents of the boiler. The hot water thus suddenly liberated at high temperature bursts into steam until the whole mass drops to a temperature of 212 degrees, and this steam is many hundred times the volume of the water from which it came. It is to this fact that the violence of boiler explosions is due.

To take an extreme case, if a boiler bursts under 500 pounds pressure, approximately thirty-seven per cent of the water it contains will pass instantly into steam, and at atmospheric pressure the volume of the steam will be over 600 times the volume of the entire original liquid contents of the boiler.

Automobile boilers and steam generators are so designed as to minimize the danger of explosion, and only ordinary care is needed to insure entire safety.

Superheating. The foregoing paragraphs have dealt exclusively with steam at the boiling temperature due to its pressure. Such steam is called "saturated" steam. Steam will not suffer a reduction of temperature below this point; if heat be absorbed from it a portion will condense. On the other hand, steam isolated from the water whence it came may be raised in temperature indefinitely. It is then called "superheated" steam. The more it is superheated the more nearly does it act like a perfect gas.

Superheated steam is preferred for power purposes to saturated steam, for the reason that the latter condenses more or less, both in the pipes on its way to the engine and in the engine itself. Steam which condenses thus is a total loss, and it is more economical to add sufficient heat to it before it reaches the engine to replaces radiation losses, etc., without cooling the steam to the saturation point. To accomplish this in automobiles, the steam from the boiler is led through one or more pipes exposed to the maximum temperature of the fire. These pipes are called superheaters, or superheating pipes.

MECHANICAL ELEMENTS OF THE STEAM ENGINE

General Details of Steam Engine Parts. In Fig. 9 a plan view of a stationary steam engine is given, with the cylinder and valve chest shown in cross section, and with the various parts marked by letters. A view of a stationary engine is used because it is not so condensed as an automobile engine, and the parts are therefore easier to mark and pick out. The relations and names of parts are the same in an automobile engine.

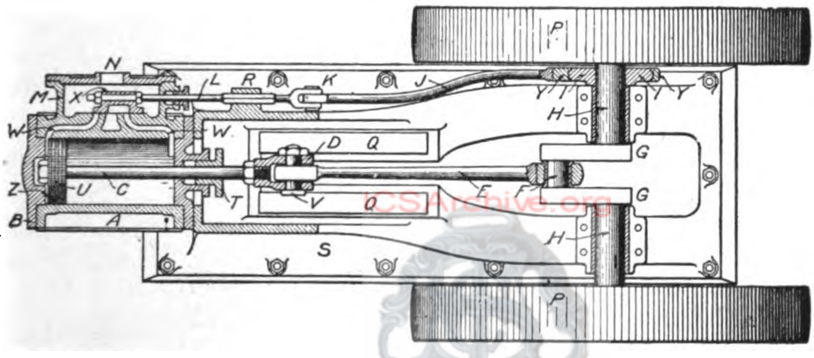


Fig. 9. Plan View of Typical Stationary Engine

A, Cylinder. *B*, Outer cylinder head. *C*, Piston rod. *D*, Crosshead. *E*, Connecting rod. *F*, Crankpin. *G*, Crank. *H*, Crankshaft. *I*, Eccentric. *J*, Eccentric rod. *K*, Eccentric crosshead. *L*, Valve stem. *M*, Steam chest. *N*, Steam pipe connection. *PP*, Flywheels. *Q*, Crosshead guides. *R*, Valve stem guide. *S*, Engine frame. *T*, Stuffing box. *U*, Piston. *V*, Wristpin. *WW*, Steam ports. *X*, Slide valve. *Y*, Eccentric strap. *Z*, Clearance space between piston and cylinder head at end of stroke.

A is the cylinder to which steam is admitted through the passages, or ports, *W W*, which connect it with the steam chest *M*. The opening and closing of these ports is accomplished by the movement of the valve *X*. Because of its shape, the valve here shown is called a D-slide valve. Other types of valves are piston valves and poppet valves, names which explain themselves. The valve is attached to the valve stem *L* and is guided by the valve-stem guide *R*. Motion back and forth is given the valve by the eccentric *I*, which is a circular disk on the crankshaft, with its center offset from the center of crankshaft *H*.

Returning to the cylinder, *U* is the piston, which is driven back and forth by the steam. Connected to the piston is the piston rod *C*, which passes through the gland, or stuffing box *T*. This gland is for the purpose of holding the packing which prevents the escape of steam around the piston rod. The end of the rod, or crosshead *D* slides back and forth in the crosshead guides *Q Q*. To the crosshead is attached the connecting rod *E*, by means of the wristpin *V*. In the lower end of the connecting rod is the crankpin *F*.

In steam automobile engines the flywheels *P P* are usually not needed and are consequently omitted. The rim of the gear wheel, when the engine is geared directly to the rear axle, has a slight flywheel action.

SLIDE VALVE

The leading mechanical elements of the steam engine have been briefly described. It remains now to show the precise manner in which the steam is used.

Elementary Slide Valve. Fig. 10 represents an elementary slide valve. In order to indicate the movements of the crankpin and the valve eccentric on one drawing, the crankshaft center is located at *A*. *B* represents the crankpin center with the piston *C* at the inner end of its stroke. The larger dotted circle is the crankpin circle, and the small circle is that in which the center *D* of the eccentric moves. With the crankpin traveling as the arrow shows, the valve is in mid-position when the piston starts to move, and the first effect of its movement is to uncover the steam port *E*, at the same time establishing com-

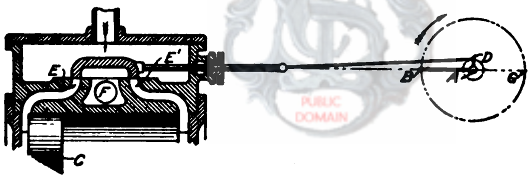


Fig. 10. Elementary Slide Valve—Valve in Mid-Position

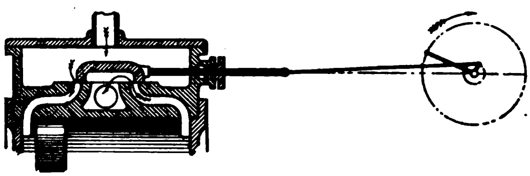


Fig. 11. Elementary Slide Valve—Inlet and Exhaust Ports Partly Uncovered

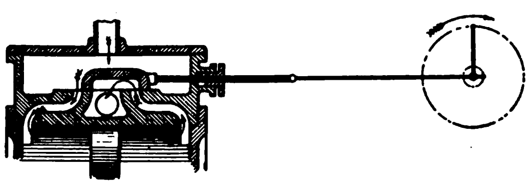


Fig. 12. Elementary Slide Valve—Inlet and Exhaust Ports Fully Opened—Piston in Mid-Position

munication between port E' and exhaust port F, Fig. 11. At half-piston stroke the ports are wide open and the valve starts to return, Fig. 12. When the crankpin reaches the outer dead center G the ports are again closed.

Use of Steam Cut-Off. A steam engine with valve arranged as above would take steam through the entire stroke, and would exhaust at boiler pressure. It would develop the maximum power of which it was capable at that pressure, but no use would have been made of

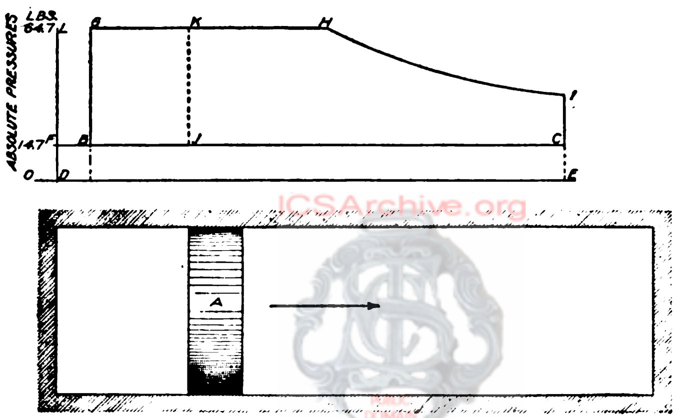


Fig. 13. Theoretical Indicator Diagram for One-Half Cut-Off

the expansion force of the steam. For this reason, all practical steam engines are made to admit steam only for the first portion of the stroke, that is, about one-half stroke or less, the remainder of the stroke being devoted to expansion. In Fig. 13, suppose A represents the position of a piston moving from left to right. The horizontal distance $B\ C$ represents the stroke, and vertical distances represent steam pressures. $D\ E$ is the line of zero pressure, and $F\ C$ that of atmospheric pressure. Suppose steam is admitted at 50 pounds gage pressure during the first half of the stroke from G to H; the steam port then closes and the steam expands with diminishing pressure along the curve $H\ I$. Since work is the product of force into distance traveled, it follows that for each fraction, such as $B\ J$ of the piston travel, the included area $B\ G\ K\ J$ will represent the work done during that portion of the stroke, and the area of the entire card $B\ G\ H\ I\ C$ will represent the work done during the whole stroke.

In the case under consideration, the area of the whole diagram is 84.4 per cent of that which would have been produced if the steam had entered during the entire stroke, yet only half as much steam is used.

Indicator Diagrams. A diagram such as Fig. 13 is called the "indicator diagram" or "indicator card", and is employed to study the internal action of the engine. The expansion curve of steam follows Boyle's Law with sufficient closeness for practical purposes. Fig. 14 is similar to Fig. 13 except that the steam is cut off at one-quarter stroke, point *H*.

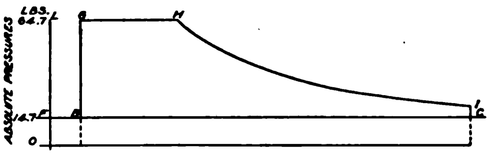


Fig. 14. Theoretical Indicator Diagram for One-Quarter Cut-Off

In the foregoing, no mention has been made of the contents of the steam passages between the slide valve and the cylinder, or of the clearance volume between the piston and the cylinder head when the crank is on dead center. These clearance spaces cannot wholly be avoided, but it is desirable to reduce them as much as possible. It is customary in indicator cards to represent the clearance space by an area to the left of the actual indicator card. This area is *F L G B* in Fig. 13 and Fig. 14. Its volume averages about 5 per cent of the volume swept by the piston. Owing to the necessity of taking the steam in the clearance space into account, the actual steam consumption in Fig. 14 is a trifle more than half that in Fig. 13.

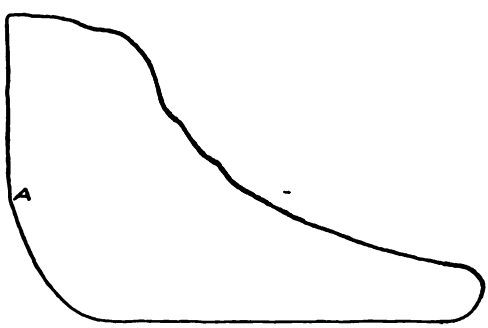


Fig. 15. Actual Indicator Card, Showing Compression

Effect of Compression on Indicator Card. The objectionable influence of the clearance may be neutralized by closing the exhaust port before the piston has finished its return stroke, thereby trapping the remaining steam at atmospheric pressure and compressing it to boiler pressure. If this is done, none of the entering steam is wasted merely in filling the clearance space. Fig. 15 shows the effect of compression on an actual indicator card. It is not carried to boiler pressure, but only to point *A*.

Another reason for using compression is to cushion the reciprocating parts at the end of their stroke and prevent the shock which may otherwise occur on suddenly admitting live steam.

Effect of High Pressure and Early Cut-Off. As Fig. 14 shows, no great advantage is gained when working with steam at 50 pounds by cutting off earlier than one-third stroke. If higher pressure is used, however, the cut-off can be considerably shortened. Fig 16 is a theoretical indicator diagram for 200 pounds gage pressure (214.7 absolute). The clearance is 5 per cent of the piston displacement, and cut-off occurs at one-tenth stroke. The weight of steam per stroke is about the same as in Fig. 14, but the work done by the higher pressure is nearly two-thirds greater. This shows strikingly the economic advantage of using high pressure, provided the cut-off is shortened to correspond.

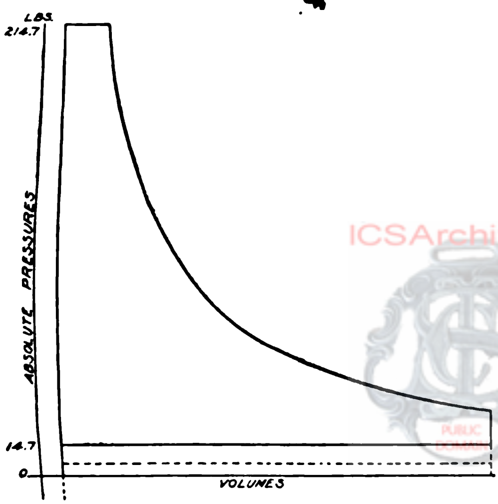


Fig. 16. Theoretical Indicator Card for One-Tenth Cut-Off

Effect of Adding Steam Lap. To produce a short cut-off, what is known as outside lap or steam lap is added to the edges of the slide valve *A A*, Fig. 17. To produce compression inside exhaust lap *B B* is also added. Figs. 18 and 19 show how the valve mechanism is affected by these changes. In Fig. 18 the piston is about to begin its stroke, but the valve is no longer in mid-position. Instead, the eccentric has had to be advanced through an angle, known as the "angle of advance", in order

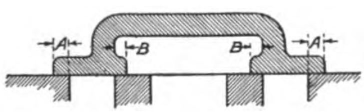


Fig. 17. Section of Slide Valve, Showing Steam and Exhaust Laps

to open the port as the piston starts to move. The necessary travel is also increased in order to accomplish the idle movement when all ports are closed. As the diagrams show, the valve reaches the end of its movement, returns, and closes the steam port while the piston is in the first quarter of its movement. It then continues to move, but with only the exhaust open.

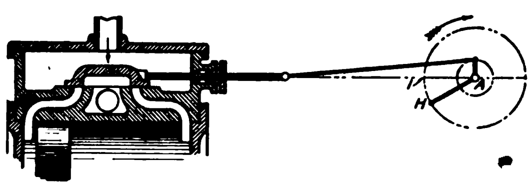


Fig. 18. Elementary Slide Valve, Showing Effect of Adding Laps

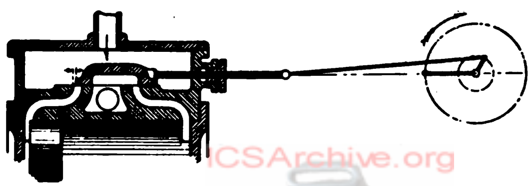


Fig. 19. Elementary Slide Valve, Showing Adjustment of Lead

It is customary, as Fig. 19 shows, to open the steam port a trifle before the piston begins its stroke in order to avoid wire drawing of the steam before the port goes fairly open. If this were not done, there would be an appreciable drop in pressure at the beginning of the stroke. The amount of this premature opening of the valve is called its "lead".

SUPERHEATED STEAM AND COMPOUND EXPANSION

Superheating to Avoid Cylinder Condensation. When steam expands its temperature drops by reason of expansion, causing the cylinder walls to assume an average temperature which slightly increases from contact with the hot steam and slightly diminishes at the end of every stroke. The hot entering steam condenses on the walls, and re-evaporates near the end of the stroke. This is very undesirable, and is avoided by superheating the steam sufficiently to compensate for the initial loss of heat to the walls. In addition, heat loss by radiation is minimized by lagging the cylinder walls and heads with asbestos, magnesia, or other non-conducting coverings.

When steam is used at pressures above 100 pounds, compound engines are preferable, although not always used.

Compound Engines. In a compound engine the work done by expansion is divided as nearly equal as practicable between two cylinders, called respectively the high-pressure and the low-pressure cylinder. The high-pressure cylinder is the smaller in diameter, and it exhausts into the low-pressure cylinder instead of into the atmosphere. In the diagram, Fig. 20, showing the elements of a compound engine, the steam is being transferred from the high-pressure cylinder to the low-pressure cylinder. The steam expands by reason of the difference in the areas of the two pistons.

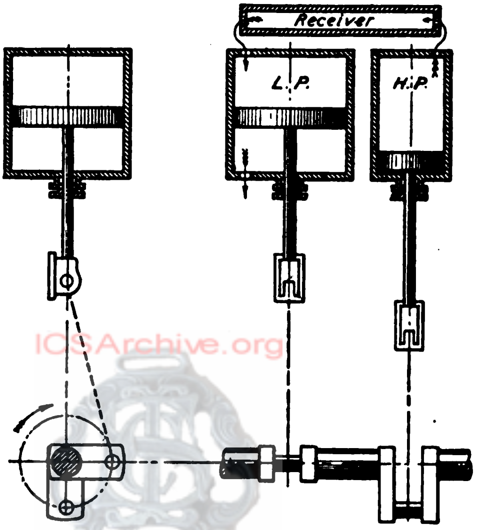


Fig. 20. Elements of a Compound Steam Engine

A compound engine may be considered as though the steam were expanded wholly in the low-pressure cylinder, and the indicator diagrams of the two cylinders may be combined to show the total work done, by shortening the horizontal distances of the high-pressure card in proportion to its smaller piston area.

Comparison of Indicator Diagrams for Stationary and Automobile Engines. Fig. 21 is a combined diagram from the high- and low-pressure cylinders of a stationary compound engine. Both cards are drawn to the same scale as regards stroke, but the low-pressure card reads from right to left. *F* is the point of admission to the high-pressure cylinder. The slight peak at *A* is due to the inertia of the in-rushing steam. At *B* the admission valve closes. At *C* the steam is released and goes into the receiver between the cylinders. *D E* is the

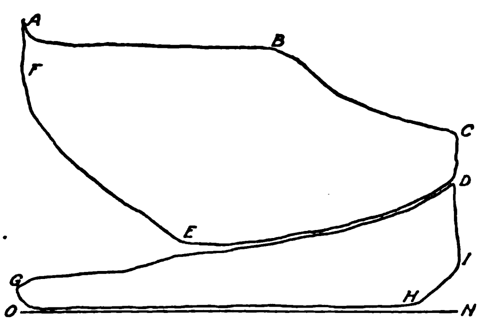


Fig. 21. Indicator Diagram of a Stationary Compound Steam Engine

exhaust line, and $E\ F$ the compression line. From D to E steam passes from the high- to the low-pressure cylinder, the difference between the two lines being due to frictional resistance of the passages. At G the exhaust valve opens. $H\ I$ is the compression line of the low-pressure cylinder.

Fig. 22 is a combined high- and low-pressure diagram from the engine of the White steam car. In this diagram the low-pressure stroke is shown lengthened in proportion to the piston area, so that

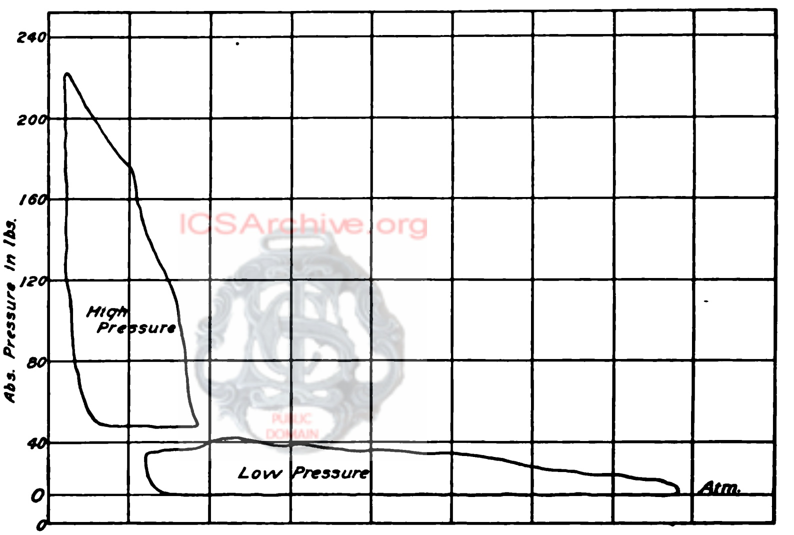


Fig. 22. Indicator Diagram of White Compound Steam Engine

the high- and low-pressure cards afford true indications of the relative work done in the cylinders.

Use of Condensers. In the foregoing paragraphs steam is supposed to be exhausted at atmospheric pressure. In other words, the steam in the working end of the cylinder must overcome a back pressure of 14.7 pounds per square inch in the exhaust end. If the exhaust steam were discharged into a closed vessel and condensed, a vacuum would be formed containing only water vapor at a pressure proportionate to its temperature. This would mean the addition of 5, 10, or even 12 pounds to the height of the indicator card without having to increase the heat units put into the steam. To do this requires considerable apparatus in the form of a condenser, vacuum

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MOTORCYCLES AND CYCLECARS

MOTORCYCLES

INTRODUCTION

Evolution of the Motorcycle. The same period which has brought the automobile to its present state of perfection has also witnessed the birth and development of the motorcycle. This two-wheeled motor vehicle was developed from the bicycle, in fact, the first motorcycles were bicycles with motors attached. However, owing to the comparatively high speed attained, the strains put upon the bicycle frame were too great, and extensive modifications were carried out, which resulted in a distinctive design and construction to stand the requirements of the service.

The motorcycle started entirely as a pleasure or sporting vehicle, used by a few bicycle enthusiasts who desired greater speed, or by racing men for pacemaking. Gradually, however, the utility of the machine in many directions became established, and now its place in its own field is as surely fixed as that of the automobile itself. For single or tandem road work, for package delivery, messenger service, military duty, and a hundred other important offices, it is unexcelled, and the thousands upon thousands of machines that are sold every year in this country alone bear testimony to its popularity.

Standard Specifications. The conventionalized American motorcycle is of two-cylinder construction. The frame is tubular and diamond shaped, with a double crossbar at the top, between which bars are located a gasoline and an oil tank. The frame at its lowest point is in the form of a loop, in which is clamped the aluminum crankcase of a twin-cylinder air-cooled motor with the cylinders set V-shaped and a carbureter fitted between. Separate exhaust pipes lead from each cylinder to a muffler. The motor is of the L-head type, with the cylinders, as a rule, cast in one piece. The exhaust valves are at one side of the motor and are operated by cams on the lower side of the crankcase. The same cam often operates both exhaust valves.

In a removable cage on the roof of the valve pocket, just over the exhaust valve, is located the intake valve, which is operated by a rocker arm above it, controlled by a push rod running up the side of the motor from the cam case. The crankcase contains two flywheels which form also the crank arms of a built-up crank. Both connecting rods are fastened to the same crankpin, and these rods run down between the flywheels.

In the cam case is a small plunger oil pump which pumps oil in small quantities to the forward cylinder, this oil being delivered through the wall of the cylinder directly onto the piston at the lower end of its stroke. From this point the oil drops into the crankcase and is thrown up through the rest of the motor by the splash system. The crankshaft on one side runs into the cam case, from which a train of gears drives a magneto for ignition. The advance and retard of this magneto are controlled by twisting one of the handlebars of the motorcycle, this motion being ordinarily transmitted to the magneto through a series of bell-cranks and rods. The throttle is controlled by twisting the opposite handlebar so that the control of the entire machine is always within the driver's grasp.

The right end of the motor shaft projects beyond the right side of the case and ends in a small roller-chain sprocket, from which a chain runs to a larger sprocket on a countershaft set at the base of —or just back of—the vertical frame tube member. Since change-speed gearsets are becoming common, this shaft is generally located back of the seat-post tube. The large countershaft sprocket connects with a small countershaft sprocket or with a gearset by means of a multiple-disk friction clutch, either of the dry fabric-faced type or of the metal type. This clutch may be operated by a lever in front of the driver's seat or by a foot pedal, or both. From the countershaft a chain runs from a smaller sprocket to a larger sprocket on the rear wheel hub of the motorcycle. In this hub is located a brake or brakes of the expanding or contracting type, or both, operating on a brake drum. The rear end of the frame is often mounted on springs from the seat-post back, the lower frame forks being pivoted and the upper connection sprung. Within this triangle and generally back of the seat post, is fitted a tool box, while over the wheel a luggage carrier forms the stock equipment. A stand is always fitted on the rear wheel to enable one to leave the motorcycle without its falling over.

The saddle is very large, as compared with a bicycle seat, and has sensitive springs, as well as being usually mounted in a spring seat post located in the vertical tube member. This saddle is always placed as low as possible on the frame. The front forks are mounted on some sort of springs—generally of the flat-leaf type—in order to absorb the shocks, and thus avoid metal fatigue in the machine as well as bodily fatigue in the rider. This in outline is the American motorcycle of today.

European Design. European practice is more varied than it is in America, the reasons being entirely manufacturing ones. In Europe, quantity-production is not the rule and hence motors have not become standardized, which fact has allowed more experimenting and greater individuality in design than has been possible in America. Here, quantity-production is the practice and this latter method has restricted the try-out to avoid mistakes, so that only established ideas have been used. The resulting standardization of the general type of American motorcycle has only been disturbed by the four-cylinder motor designs and by small-quantity production of two-cycle motors.

HISTORY

Early Machines. The first motorcycle built was the work of Gottlieb Daimler, who, in 1885 built a two-wheeled vehicle to try-out a gasoline motor with which he was experimenting. This machine was the forerunner not only of the motorcycle but of the automobile as well. De Dion of France, with Karl Benz of Germany, developed along with the automobile the gasoline motor, and the De Dion type was soon applied to a motor-tricycle, followed by a motor-bicycle using the same motor.

This motor was the predecessor of the motorcycle motor of today. The cylinder arrangement and the location of the compression chamber were almost identical. Two flywheels were used with a connecting rod between, and the flywheels were entirely enclosed in the crankcase. Viewed in the light of modern design the motor was very crude but developed horsepower enough to drive this early machine at what was then considered an astonishing speed of 30 miles per hour.

The foreign machines were developed between 1894 and 1898, when an American inventor who had been building racing bicycles, took up the motor-driven tandem as a pacemaking mount for bicycle racing. As the motorcycle is all wheelbase and no tread, it has no difficulty in holding the road at any speed, a fact which made it very adaptable to this kind of service. The transmission of this machine, designed by Oscar Hedstrom, was the basis of the formation of a company for the manufacture of motor-bicycles, with George M. Hendee as the business manager of the concern. At about the same time, the Thomas, Holly, Orient, and Mitchell motorcycles were being developed.

Two-Cylinder Motors. Glenn Curtiss was one of the first to develop a two-cylinder motor. It was in connection with his experiments with motors that he built a motorcycle equipped with an eight-cylinder V-type motor, which, covering a mile in 26.4 seconds—the fastest mile ever covered by man—held the record until recent date.

The first motors built were small-power engines of about the same stroke as bore; they attained surprising speed and cooled very successfully with flanges of small area.

Starting with 2.5-horsepower motors, power and weight were continually added until motors of 12- and even 14-horsepower have become common practice. The latter are for the most part of large bore and of comparatively slow speed, but, through the activity of European developments, light-weight machines with high-speed motors are coming into prominence.

Influence of High-Speed Motors. In the early days, when materials and workmanship were questionable, except at a great expense, high speed in a motor was a disadvantage and tended toward short life. Belt drive from the motor to the rear wheels was common, and hence motors could not be geared below a certain ratio without having the belt pulley too small to transmit the power. Flat belts became very popular in America and were used on such machines as the Excelsior, Harley-Davidson, Yale, etc., while the Reading-Standard and the Indian factories consistently held to chain drive. Within the past few years, with the introduction of change-speed gears and high-speed motors, a positive drive has become a necessity and chain drive with reduction to a countershaft located between the motor and the rear wheel has become almost standard practice.

Foreign designers still favor the belt to transmit the power from the countershaft to the rear wheel, claiming greater flexibility of drive. American makers obtain smoothness of action by incorporating a slipping clutch in the transmission.

Light-Weight Machine. First to bring into prominence the light-weight motorcycle and high-speed motor was the Douglas Company, of England, which built a small horizontal-opposed, two-cylinder, air-cooled motor which, through its almost perfect balance of moving parts, proved successful above 4000 r.p.m. This motor was set fore-and-aft in a light frame with a chain taking the power from the motor to a countershaft at the frame junction below. A V-type pulley was the front member of the belt-driven system and the gear reduction of the first chain drive threw a minimum strain on the belt and hence proved very reliable. This machine weighed, complete, about 183 pounds and yet was capable of the same road performance as the high-powered American machines of greater weight.

Other makers have followed the lead of this firm in developing what are known as light-weight motors, and America has taken up the idea, although road conditions do not allow the extreme lightness which is possible abroad.

Modern Improvements. Single-cylinder motorcycles are very rare in America today, the preference being for high-power, twin-cylinder mounts. The greatest improvements of recent date have been toward making the motorcycle more comfortable, cleaner, easier to operate, more reliable, and more foolproof. This, in nearly every case, has meant increased rather than decreased cost, but buyers prefer a completely equipped machine at higher prices to partially developed mounts at lower figures. Four-cylinder machines are becoming popular with each succeeding year, and the manufacturers are also incorporating three-speed gearsets, self-starting systems, and other automobile features to as great an extent as possible.

With the many improvements in construction, convenience and reliability in the motorcycle has come a broadening of its field of usefulness. Fitted with a side and an extra wheel, it has become the family carryall or has been utilized for city runs and delivery purposes. In the recent wars, motorcycles have played a very important part in the transmission of messages and in the quick dispatch of repair men and scouts for emergency service. A number of the sidecar vehicles have even been fitted with machine guns and very successfully used for rapid reconnoissance work.

TYPES OF MOTORCYCLES

Excelsior. An Excelsior machine, shown in Fig. 1, is equipped with a twin-cylinder V-type 10-horsepower motor, chain drive and two-speed crankshaft gear. The frame has an exceptional amount of drop at the rear, allowing the rider to sit very low—close to the ground. The front forks are fitted with a leaf spring shock-absorbing device, the seat is hung on the usual spring-tube construction and

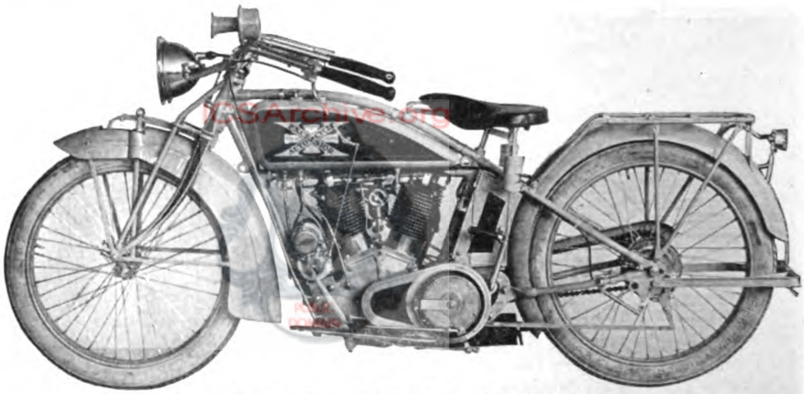

Fig. 1. Excelsior Model 15-3 Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago

the side springs themselves are incased. Contracting- and expanding-band brakes are used on the rear wheel, and no pedals are used on the model shown. This machine is chain-driven, has a gearset on the countershaft giving three speeds, an electric lighting and ignition system, a kick starter, and extra long footboards. The equipment is exceptionally complete. The details of these various mechanisms and those of other motorcycles will be described later.

Indian. The Indian motorcycle, shown in Fig. 2, is driven by a twin-cylinder motor for which a 15-horsepower output is claimed. A feature of this machine is the hanging of the entire mechanism on leaf springs, both front and rear. It is chain-driven, fitted with a dry-disk clutch and is equipped with either two- or three-speed gear. This gear is of the sliding type, and is located in the countershaft.

No pedals are used, the motor being depended upon entirely for power, and starting being obtained by a kick pedal, as described later.

Harley-Davidson. The Harley-Davidson twin-cylinder motorcycle is shown in Fig. 3. It is fitted with an 11-horsepower motor,

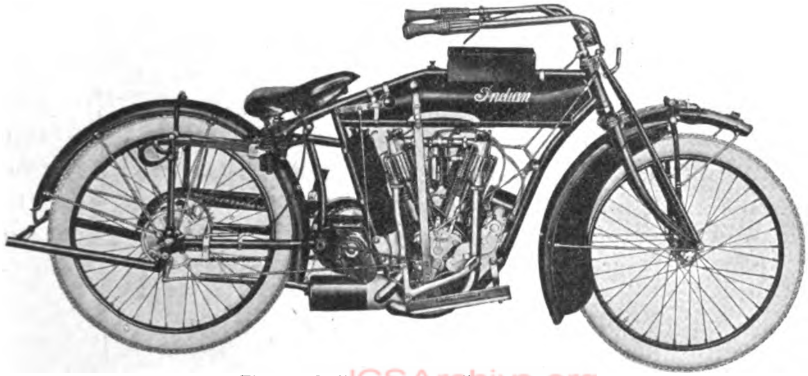

Fig. 2. Indian "Big Twin" Motorcycle
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

chain drive, and a three-speed gearset. It is equipped also with footboard, foot control, luggage carrier, and stand, and has a special type of spring seat for absorbing road shocks. The oil feed for the

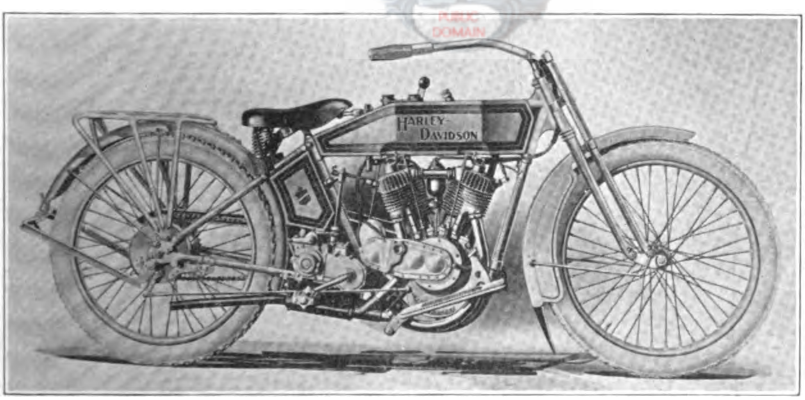

Fig. 3. Harley-Davidson Twin-Cylinder Motorcycle
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

motor is by a special type of plunger pump. Coil spring forks are used instead of leaf springs, as in the models already mentioned.

Dayton. The Dayton motorcycle, shown in Fig. 4, is of conventional design, fitted with a V-type motor, footboards, and clutch and is obtainable also with a two-speed gear. The clutch is of the multiple dry-disk type.

Flying Merkel. The Merkel motorcycle, shown in Fig. 5, obtains the springing effect by a spring plunger located under the saddle at

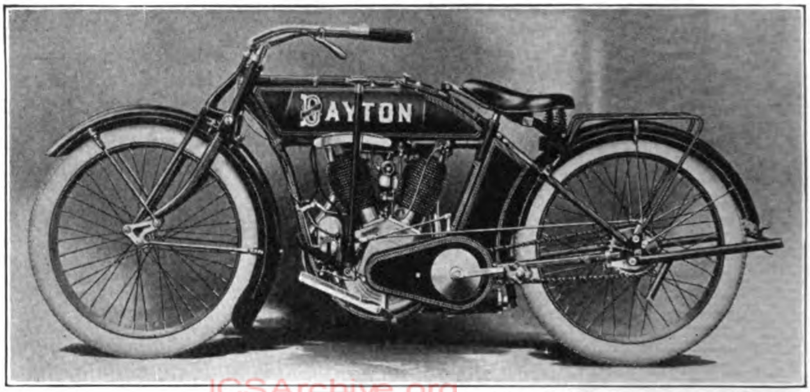

Fig. 4. Dayton Twin-Cylinder Motorcycle
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

the angle of the rear upper forks. The lower forks are pivoted about the pedal shaft, thus springing the whole rear end of the frame on a coil spring, quite unlike the other types using leaf or coiled springs.

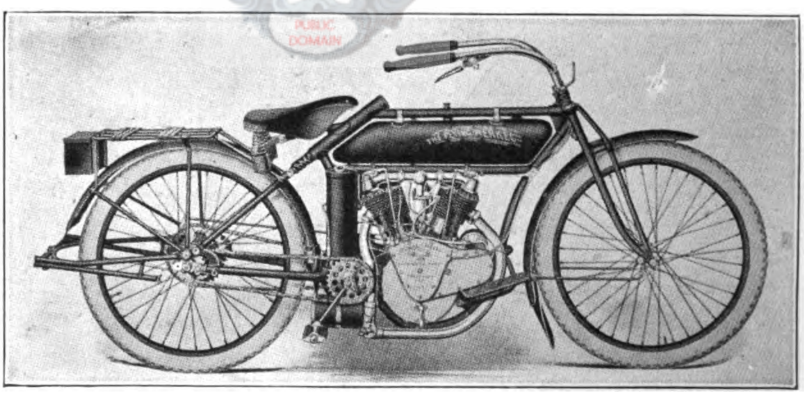

Fig. 5. Flying Merkel Twin-Cylinder Motorcycle
Courtesy of Miami Cycle and Manufacturing Company, Middletown, Ohio

The Merkel is fitted with a 9-horsepower twin motor and chain drive. It is started with a kick starter and may be obtained with a two-speed planetary crankshaft gear. The clutch is of the metal-disk type running in oil.

Pope. All the motorcycles mentioned so far are fitted with L-head V-shaped motors with the inlet valve located over the exhaust and operated by an overhead rocker arm and push rod.

The Pope, illustrated in Fig. 6, departs from this usual practice

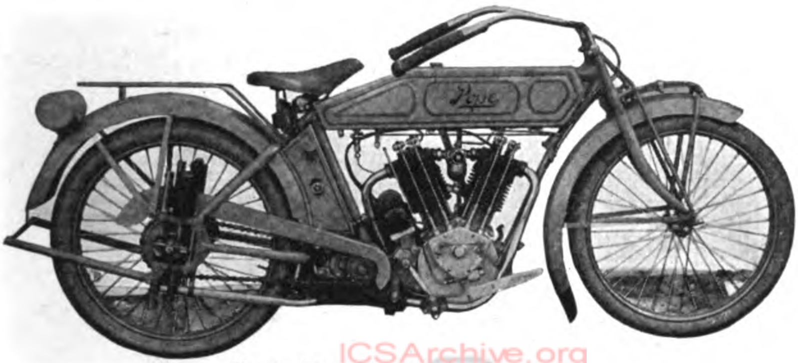

Fig. 6. Pope Twin-Cylinder Motorcycle
Courtesy of Pope Manufacturing Company, Westfield, Massachusetts

by employing an extra-efficient 15-horsepower air-cooled V-type motor with overhead valves. The motorcycle otherwise is standard. The front fork has a leaf spring, while the rear-wheel vibration is

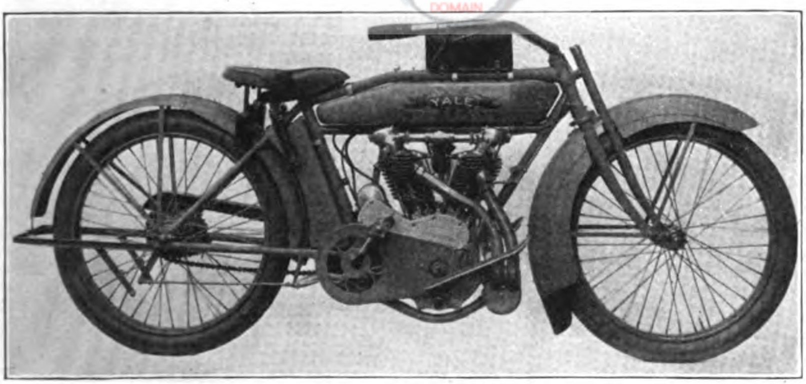

Fig. 7. Yale Twin-Cylinder Motorcycle
Courtesy of Consolidated Manufacturing Company, Toledo, Ohio

absorbed by having the wheel mounted on both sides on plungers which are so connected with coiled springs that they support the whole rear end of the machine. This machine is very fast and is said to be very comfortable.

Yale. The Yale motorcycle, Fig. 7, has as a feature a twin motor with cooling fins on the cylinders cast horizontally, that is, on the line of the air current, with the idea of obtaining a greater amount of cooling. The motor is of the high-speed type, with the valves in the conventional side location. The front fork is of the coil-spring-and-plunger type. The seat is supported on extra springs to add to the rider's comfort. A two-speed gear is provided on the countershaft. Drive from motor to countershaft is by chain, a second chain taking the drive from here to the rear.

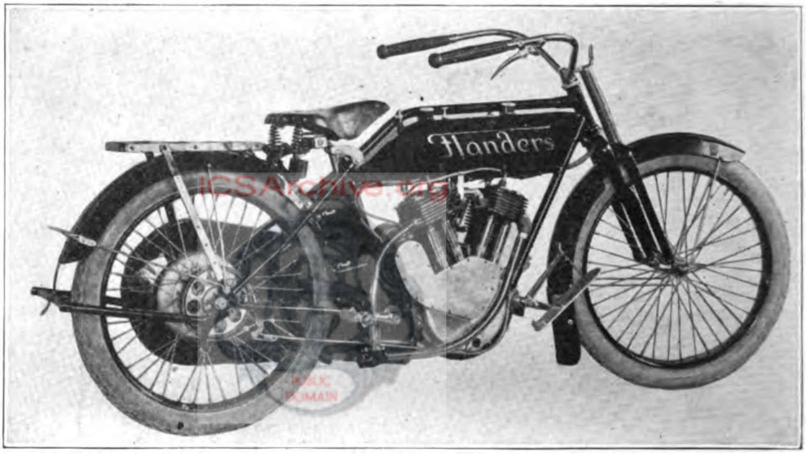

Fig. 8. Flanders Twin Motorcycle
Courtesy of Motor Products Company, Detroit, Michigan

Flanders. The Flanders motorcycle, shown in Fig. 8, is distinguished by its direct drive from the motor to the rear wheel. This is accomplished by the use of a large sprocket at the rear. The driving chain is ordinarily incased in a dustproof covering, and is extra silent. This construction eliminates crankshaft troubles and delivers a maximum of power to the rear wheels.

Thor. The Thor motorcycle, Fig. 9, has the usual twin motor and also has a low seat like the Excelsior. It has both pedals and foot rests and is equipped with electric head- and tail-lights.

Shickel. A unique feature of the Shickel motorcycle is the two-stroke, valveless, single-cylinder motor. This has a rating of six horsepower and is a very simple and efficient motor. This motorcycle has an individual feature in the unit tank and frame construction which has proved very satisfactory. A chain drive with one reduction or a direct belt drive, Fig. 10, is provided. This

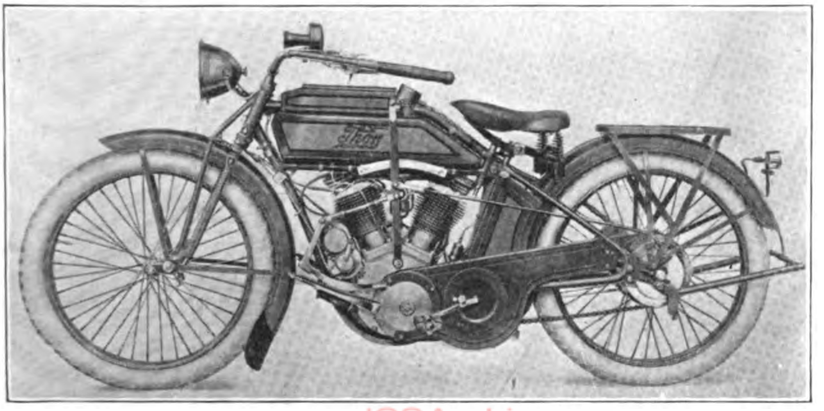

Fig. 9. Thor Twin-Cylinder Motorcycle
Courtesy of Aurora Automatic Machinery Company, Chicago

Company also manufactures a small motorcycle weighing 95 pounds and a motor attachment for a bicycle.

Henderson. The four-cylinder motorcycle is growing in favor in America. One of its chief advantages is its ability to run at

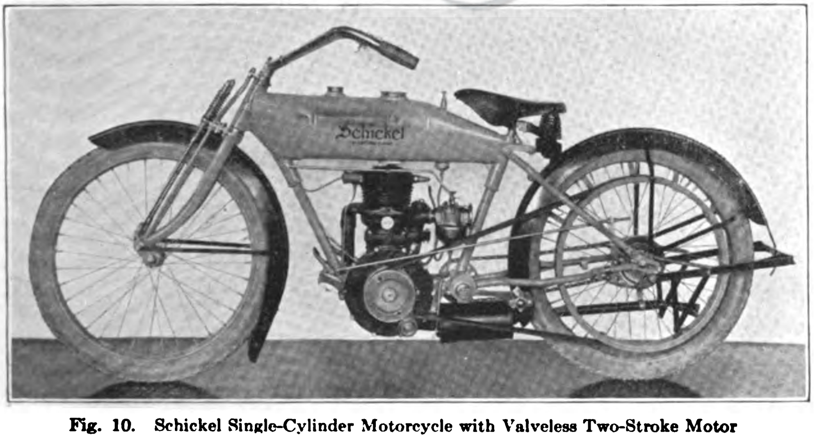

Fig. 10. Schickel Single-Cylinder Motorcycle with Valveless Two-Stroke Motor
Courtesy of The Schickel Motor Company, Stamford, Connecticut

exceptionally low speeds when the traffic is heavy and to accelerate with wonderful rapidity. An example of this type, the Henderson, is shown in Fig. 11. Its construction is especially compact and follows automobile practice largely. It is very low-hung, silent in operation, flexible, and fast. The motor is mounted directly under the driver's seat, leaving space up forward for a large, comfortable foot-board and easy-acting control pedals. The motor is started by a crank fitted at the side of the machine. A contracting-band brake at the rear is operated from one of the foot pedals. A two-speed planetary gearset is obtainable on this machine for an extra charge. The front fork is of the plunger and coil-spring type, but there is no special springing feature at the rear.

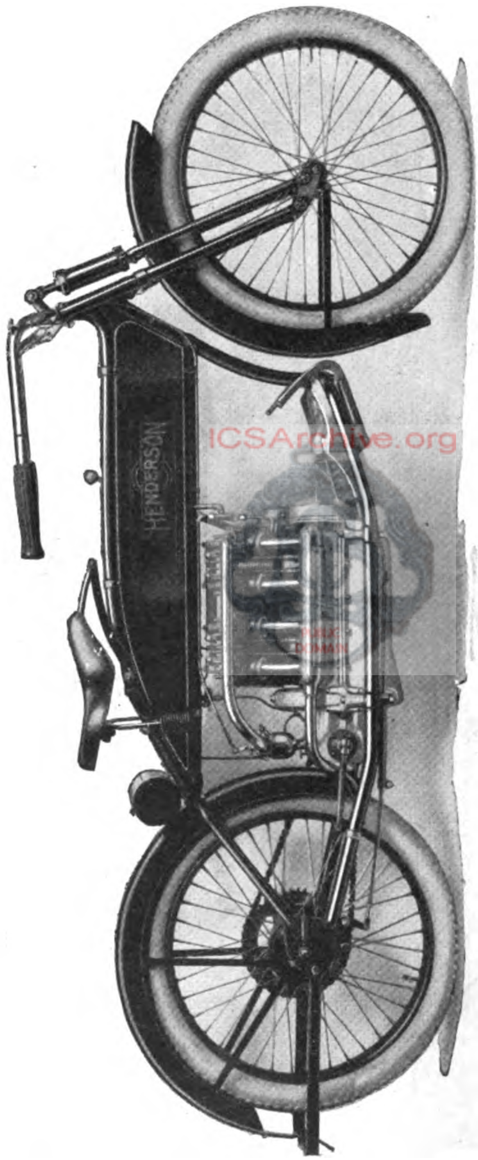

Fig. 11. Henderson Four-Cylinder Motorcycle
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

CONSTRUCTION DETAILS

Spring and Frame Construction. *Seat-Post Springs.* The springs used on a motorcycle to absorb the road shocks or add to the comfort of the rider are usually located on the front forks, in the rear frame, or in the seat post. One of the first firms to adopt a spring seat post was the Harley-Davidson, but the Merkel had used a spring-frame construction some time previous. The more prominent of the modern spring constructions are illustrated below.

The *Merkel* spring-frame construction is shown in Fig. 12, a coil spring being fitted under the saddle and forming a continuation of the upper forks. In action the lower forks are pivoted about the crankshaft of the motor below, this acting as a radius for the rear axle. The upper forks support the entire weight of the motorcycle on the coil spring.

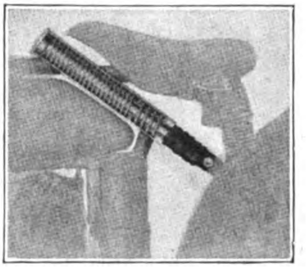

Fig. 12. Flying Merkel Spring Seat Post

The *Harley-Davidson* and the *Dayton* systems, which are very similar, are illustrated in Figs. 13 and 14. In this construction the vertical tube of the frame contains a plunger operated from a fixed center with a coil spring on either side. The saddle fastens to a radius rod at the

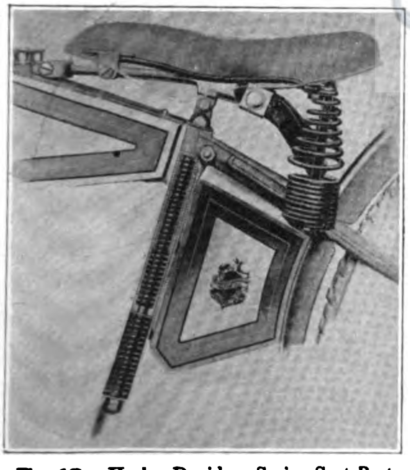

Fig. 13. Harley-Davidson Spring Seat Post

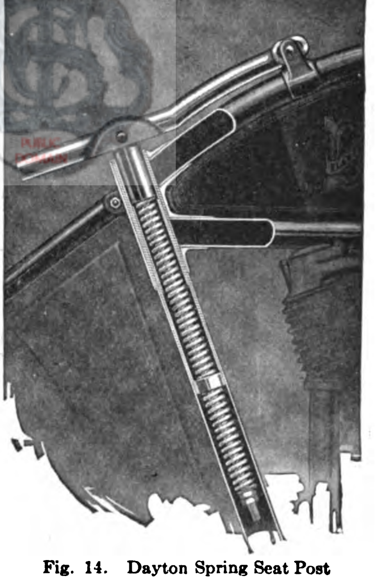

Fig. 14. Dayton Spring Seat Post

top of this plunger, the front end of this radius rod being bolted to a clutch on the frame. The entire weight of the rider is supported through the saddle on the coil spring below, allowing a very easy-riding action.

Rear and Front Frame Springs. The Pope uses a leaf-spring front fork and a spring type of rear suspension, Fig. 15. The latter consists of a drop-forged bracket on each side brazed to the rear end of the frame with a tension spring fastened to the top surface of the bracket. Double guide rods, as shown in the figure, are used on the model illustrated in Fig. 6, these rods carrying an axle yoke which is free to move between the jaws of the bracket, thus allowing the spring to absorb the rear vibration. Fig. 16 illustrates the *Indian* cradle-spring frame at the rear. This construction has the lower forks pivoted, as on the Merkel, but the weight of machine and rider is supported on the two leaf springs, as shown. The details of the front-fork leaf springs of the Indian are shown in Fig. 17.

Fig. 15. Pope Rear Frame Spring Arrangement

Fig. 16. Indian Rear Cradle-Spring Frame

Types of Frames. There are two types of frames ordinarily used in motorcycle construction. The one is formed with a loop, as shown in Fig. 18, the motor fastening to lugs on either side of the loop. This construction makes the machine very easy to assemble and the frame is equally strong whether the motor is in or out of the frame. The other construction is similar to this, except that the loop

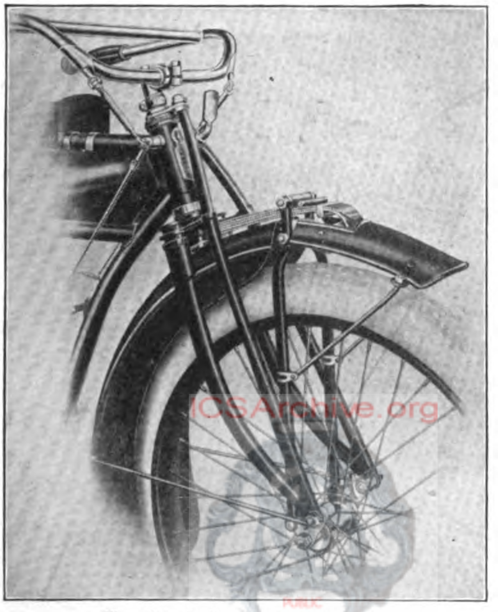

Fig. 17. Indian Front-Leaf Spring

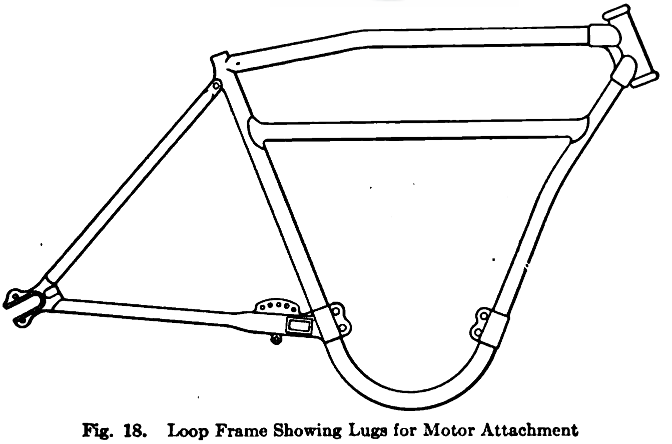

Fig. 18. Loop Frame Showing Lugs for Motor Attachment

below is eliminated, as shown very noticeably in Fig. 7. The lugs fasten directly to the crankcase of the motor, which thus becomes the lower member of the frame.

Motors. Motors for motorcycle use are usually of the four-cycle air-cooled variety. These, as previously described, are now built with one, two, and four cylinders. Water-cooling has been tried abroad on motorcycles with considerable success, but so far has not been applied in America.

Single-Cylinder Type. A single-cylinder type of motor is illustrated in Fig. 19. This is an L-head motor with exhaust valve below and the inlet valve above, operated by a long push rod. The car-

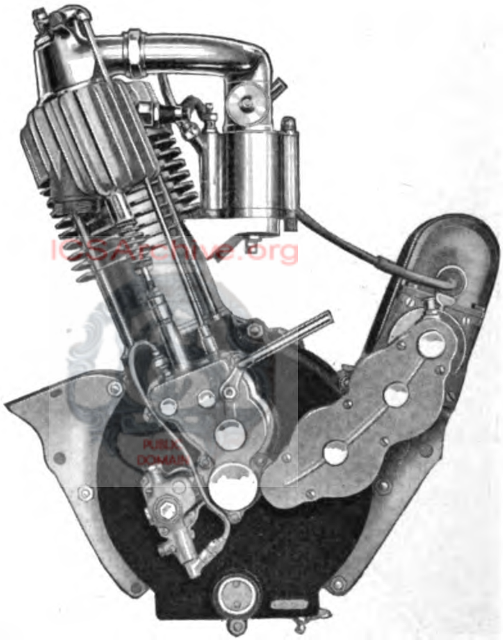

Fig. 19. Single-Cylinder Motor with Mechanical Oiler Shown at Side of Crankcase
Hendee Manufacturing Company, Springfield, Massachusetts

bureter is shown above connected by a pipe to the inlet manifold. The magneto, connected to the motor by a train of gears, is shown at the right. This illustration is of an early type of motor used on the Indian motorcycle.

Two-Cylinder Type. Most motors on the machines of today are of the two-cylinder V-type, a typical example being the Harley-Davidson, shown in Fig. 20. The magneto will be noted on the left, and the carbureter at the top between the cylinders. The cylinders are arranged in a V-shape with their center lines meeting at the center of the crank. Both connecting rods act on one crankpin. The exhaust valves are inclosed in the large tubes to be noted at the side of each cylinder.

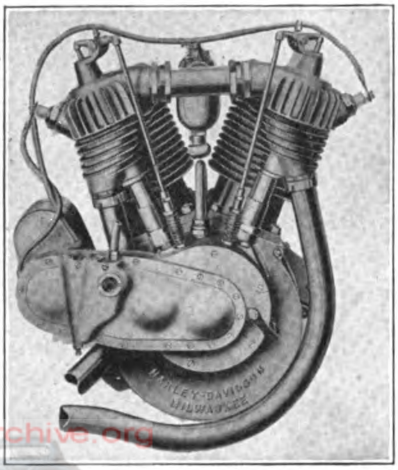

Fig. 20. Harley-Davidson Twin-Cylinder Motor

The overhead inlet valves are operated by long push rods attached to rocker arms on top of each cylinder. The long curved pipe at the right is the exhaust pipe, leading from the forward cylinder. A pipe leads from the rear cylinder, these two pipes remaining separate until they reach the muffler. Other motors of the conventional V-type may be noticed on the cuts of the different motorcycles already illustrated. A V-motor with overhead valves is used on the Pope motorcycle, as shown in Fig. 21. This type of motor is in outline almost the same as the other ones shown, except that both inlet and exhaust valves are located in the head of the cylinder for extra efficiency, and both are operated by long push rods and overhead rocker arms, as shown. The carbureter is in the usual location.

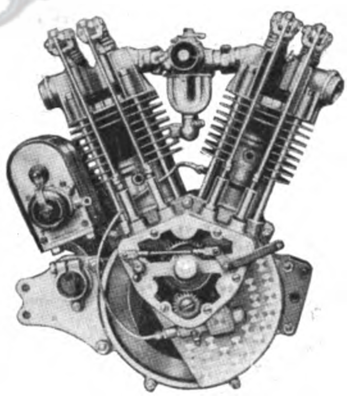

Fig. 21. Pope Twin Motor with Overhead Inlet and Exhaust Valves

Four-Cylinder Type. Figs. 22 and 23 illustrate the Henderson four-cylinder motorcycle. This is also air-cooled and of the L-head type with overhead inlet valve. It is designed for medium-high speed, has a three-bearing four-throw crankshaft, three-ring pistons, an enclosed flywheel, and a bevel-gear reduction. The motor is lubricated by splash from the oil in the base of the crankcase, as will be noted by Fig. 23. This motor is particularly neat, noiseless, and flexible.

European High-Speed Type. Foreigners with their generous experimenting have gone farther in motorcycle design than have our designers in America. This progress, however, has been in the line of experimental work and individual building than in workmanship

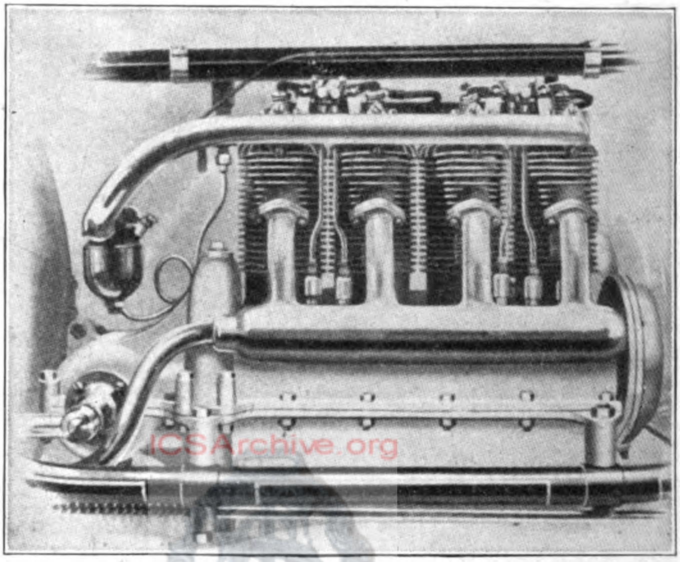

Fig. 22. Side View of Henderson Four-Cylinder Motor

or in accuracy of production, the latter being the American's strong specialization. America, in spite of its heavy road conditions, is not experimenting with water-cooled motors for motorcycles, though

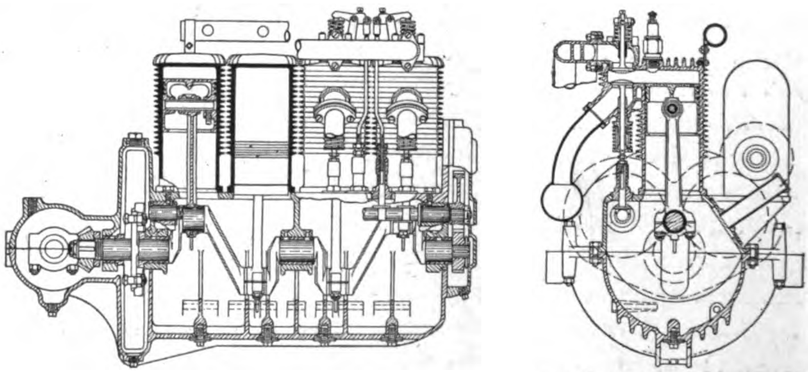

Fig. 23. Longitudinal- and Cross-Sectional Views of Henderson Four-Cylinder Motor

England uses them to a limited extent. One of the most prominent motorcycle builders in England departs from standard practice in adopting both water-cooled and two-cycle principles. Consistent performance as a result of these innovations, coupled with good workmanship, has given this machine great prominence.

Europe's greatest advantage, however, in motorcycle construction has been exemplified by the development of the high-speed motorcycle motor. This is ordinarily of the horizontal-opposed type, the most prominent high-speed low-weight construction being the Douglas, a British machine. This motor is able to maintain this high speed through a crankshaft balance which is practically perfect, allowing it to run at the abnormally high speed of 4000 r.p.m. for long periods without fatigue of material, and hence with great efficiency. The motor is of the L-head type with air-cooled cylinders and an outside flywheel. The cylinders being placed opposite each other, the counterbalanced cranks are set 180 degrees apart. The entire motorcycle is said to weigh under 200 pounds and attains speeds well above a mile a minute.

As the high-speed motor is attaining prominence in the automobile world it is very probable that the foreign type of motor will be seen in America within a short time.

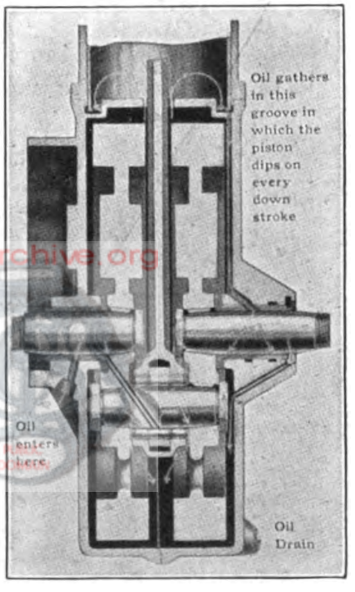

Fig. 24. Excelsior Lubricating Systems

Lubrication. *Path of Oil.* A lubricating system as used on the Excelsior motorcycle motor is shown in Fig. 24, and gives the particularly neat method by which motors of this type are oiled. In this case, the oil is first fed to the main bearing on the cam case side, as shown by the arrow. This oil is fed by pressure from a pump and, after covering this bearing, is forced out at the end and flows through the drill hole shown, this bringing it out above by centrifugal force to the connecting-rod bearing. This bearing throws the excess oil out, splashing it in all directions and up through the slot through which the connecting rod runs. From here it runs out on either side and gathers in a groove at the bottom edge of the cylinder. The bottom of the piston drops into this trough of oil every time it comes down, thus carrying the even film with it up the walls of the cylinder. Excess from here flows down the side of the crankcase and feeds the right-hand bearing. Excess from here is caught on the outer end of the shaft and returned to the crankcase, where it is splashed up again into the motor for further use.

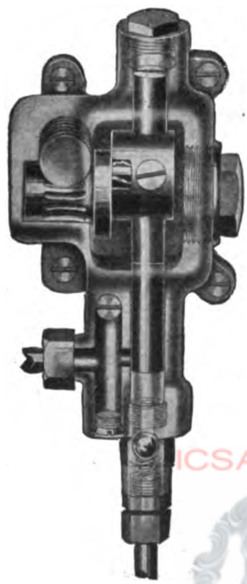

Fig. 25. Excelsior Oil Pump

In a V-type twin-cylinder motor where the oil trough at the bottom of the cylinder cannot catch an even amount on account of the cylinder angularity, the oil is generally allowed to drain back at once on the rear cylinder, and instead of feeding oil to one of the main bearings first, this oil is fed to the forward cylinder by the pump.

Oil Pumps. Fig. 25 shows a type of oil pump which is used to feed the oil to the motor. By this construction a small worm drive from the cam case or magneto gear case turns a small crank which operates a vertical plunger. This plunger cylinder is so arranged that on the top of the stroke oil may flow into the cylinder space, a ball check valve holding the oil from being sucked into the cylinder. On the down stroke, the oil inlet is covered by the piston and the ball check valve opens to allow the plunger to force the cylinderful of oil out of the motor.

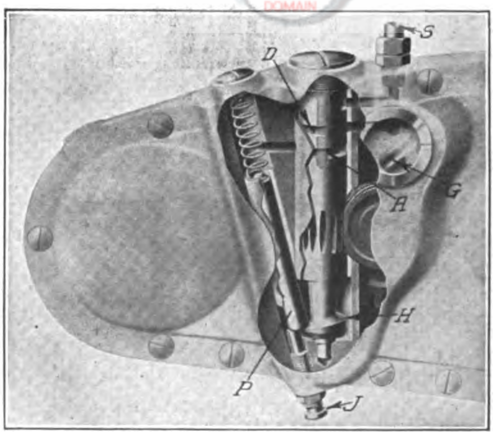

Fig. 26. Indian Roller-Cam Pump

Fig. 26 illustrates a special type of pump, in which the plunger *P* is operated by a peculiar-shaped roller cam *H*. The shaft of this roller cam contains the elements of a rotary valve, with openings at A and D, so that the oil is fed positively through a sight feed G on its way to the motor. There are no ball check valves in this construction and a screw J enables one to adjust the amount of oil delivered to the motor within very narrow limits. The intake oil pipe is shown at S. The oil is fed to the motor through the opening G. Since oiling is so important a part of the high-speed motor operation the development of this device has made a change in the reliability of the modern motorcycle.

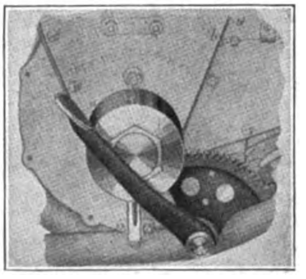

Fig. 27. Flying Merkel Kick Starter

Ignition. The ignition of the modern motorcycle is invariably by magneto, so that no description is necessary other than is given under magneto theory and construction in the section on Electrical Equipment.

Starting. It is hardly probable that the complication of electric starting will be adopted widely for motorcycle use, as it is generally

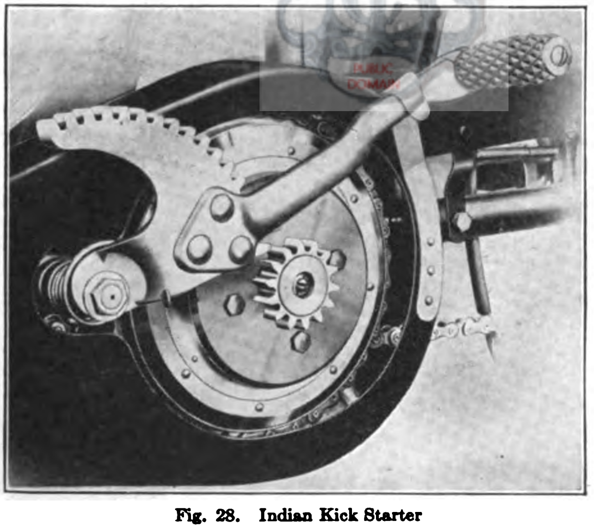

Fig. 28. Indian Kick Starter
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

more trouble to operate a power starter and keep it in repair than to use the simple form of kick starter which has become so popular and which now is fitted to almost all American machines.

Figures 27 and 28 show forms of starters in use on the Merkel and Indian motorcycles, respectively. The main shaft on one side or the other is fitted with a small gear pinion, which is fastened to the shaft on a ratchet or over-running clutch. Off to one side is pivoted a gear quadrant fastened to a pedal, which is often of the folding type. Pushing down on this pedal with the foot meshes the pinion with the quadrant and a quick thrust or kick of a quarter-turn will then turn the motor over several times at fair speed. When the motor starts, the small pinion is released and a strong pull brings the quadrant back to its former position out of

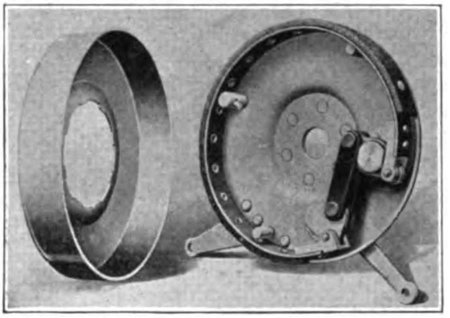

Fig. 29. Typical Expanding-Band Brake
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

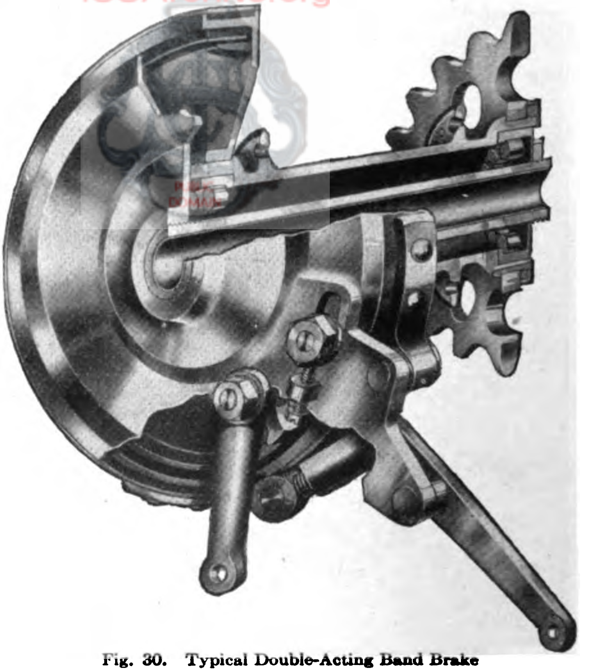

Fig. 30. Typical Double-Acting Band Brake
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago

mesh with its pinion. The pedal is generally fastened in this upward position by means of a clip so that it cannot rattle.

Brakes. A number of types of brake construction are used on motorcycles but they are mostly of the expanding- or contracting-band variety. Fig. 29 shows the construction of an expanding-band brake. The band, shown at *B*, is of springy material and covered with a brake-lining material *F*. This shoe or ring fits inside the brake drum *D*, which is keyed to the rear wheel hub. Operation of the lever *L* pushes the ends of the band *B* apart so that it expands forcibly against the interior of the drum *D*.

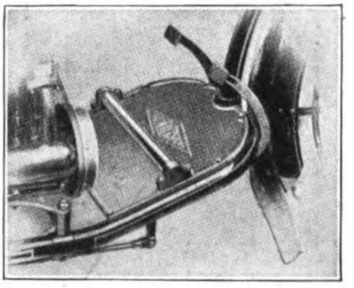

Fig. 31. Henderson Foot Rest and Brake Pedals

A similar band may be fitted outside the drum, but in this case the fabric will be on the inside of the band, and the lever will pull the band tight on the outside of the drum. This is known as the contracting-band brake. Fig. 30 shows the brake used on the Excelsior motorcycle combining both types, the expanding and contracting bands being shown in section with their linings in place. The operation is by two levers shown in the lower part of the illustration.

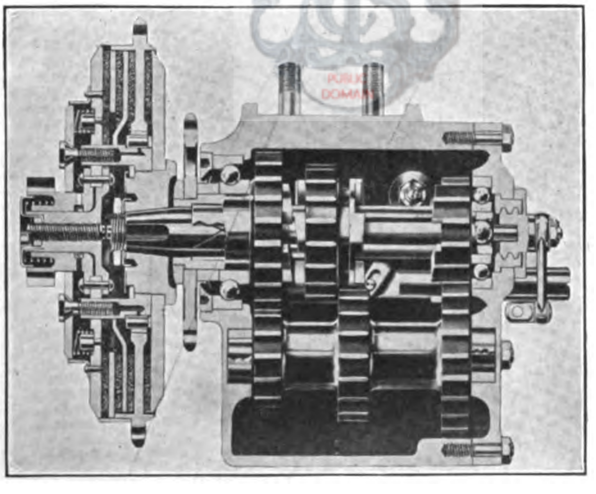

Fig. 32. Indian Multiple-Disk Clutch and 3-Speed Gearset

Fig. 31 illustrates the pedals fitted to the Henderson motorcycle, and operating the brakes of this complete little machine.

Drive. *Belt Drive.* The simplest form of motorcycle transmission, and one which until recently was commonly used, consists of a belt running over two V-shaped, or flat-faced pulleys, as shown in Fig. 10. One pulley is attached to the crankshaft of the motor, and the other to the hub of the rear wheel. With the increasing power of modern motors a successful belt drive is becoming almost impossible from the limitation in pulley sizes possible with motorcycle construction.

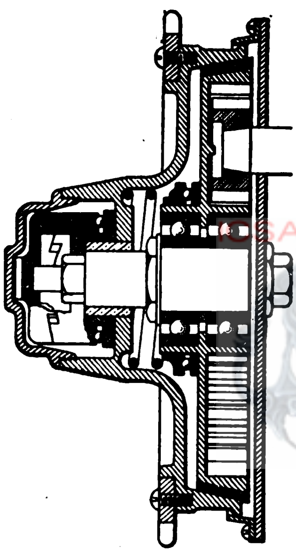

Fig. 33. Sectional View of Reading-Standard Cone Clutch

Shaft Drive. The Pierce Company of Buffalo built a number of shaft-driven motorcycles a few years ago, but at present none of this type are being manufactured in this country. With a four-cylinder motor, shaft drive is very practicable and probably will be revived as four-cylinder machines become more popular.

Chains. The highest degree of efficiency is obtained with a single chain running over sprockets on the crankshaft of the motor and on the hub of the rear wheel, as on a bicycle. Such a transmission is found on the Flanders twin-cylinder machine, Fig. 8, and has proved very successful. In this particular instance a chain case is used to avoid dust and to hold an oil supply.

Clutches. Several kinds of clutches are used on motorcycles, the one most used being of the multiple-dry-disk type, as shown at the left end of Fig. 32. This consists of a number of thin metallic disks faced with fabric brake-lining material and keyed alternately to the center shaft and the containing drum. When springs are allowed to thrust these plates tightly together the amount of friction generated makes a reliable drive between the drum and the central shaft. Suitable mechanism is arranged so that, when it is desired to disengage the clutch, a lever or pedal can release this spring pressure and allow the disks to run free without friction between them.

Metal-to-metal clutches consist of a set of metal disks brought into or out of contact by means of a lever. These are generally run in oil to prevent their heating. When the spring pressure is applied

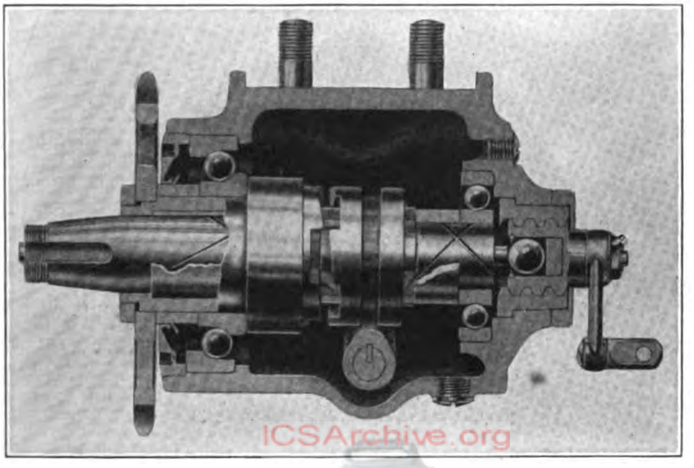

Fig. 34. Indian Neutral Countershaft
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

it takes a number of revolutions to drive out the oil from between the plates and thus prevents a grabbing clutch.

The Reading-Standard motorcycle, instead of employing a countershaft back of the motor, fits an internal-gear countershaft to the side of the crankcase and drives from this to the main-drive sprocket by means of an ordinary automobile-type cone clutch.

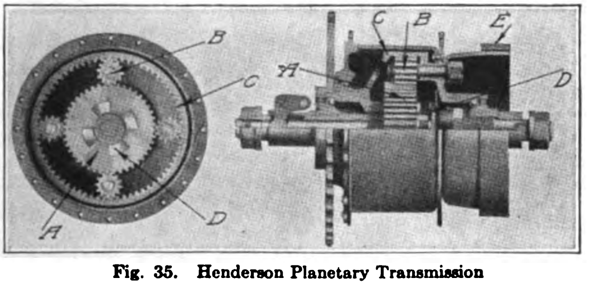

Fig. 35. Henderson Planetary Transmission

This is shown in Fig. 33. A cone on this clutch is faced with leather and operates exactly like an automobile clutch.

Gearsets or Change-Speed Mechanisms. Modern motorcycles are almost invariably fitted with change-speed gears which might be classed as one, two, and three-speed types.

One-Speed. The one-speed gear—if it can be so called—is merely a dog clutch arrangement, Fig. 34, used to disconnect the motor from the rear wheels when the clutch is in engagement. The central part is a ring which can be moved from right to left in order to fit the notches in its face into those on an adjacent ring connected to the driving sprocket. The sliding of this member is accomplished by means of the small lever.

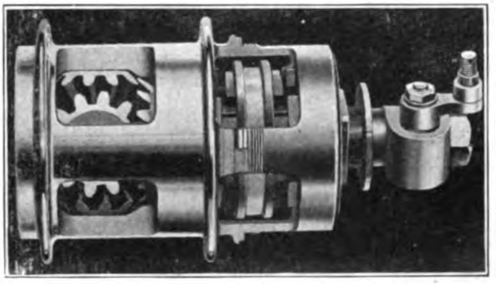

Fig. 36. Harley-Davidson Two-Speed Gearset

Two-Speed Planetary. The two-speed gear is the most common one in use for motorcycles and may be found in two varieties, planetary—or epicyclic—and sliding. The principle of the epicyclic type is explained in Fig. 35, which is a cut of the two-speed gearset used on the Henderson four-cylinder motorcycle.

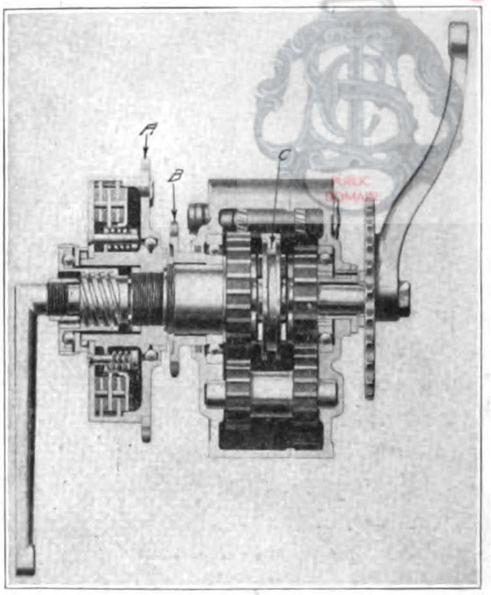

Fig. 37. Dayton Multiple-Disk Clutch and Sliding-Gear, Two-Speed Transmission

First, there is a central toothed wheel, a spur gear, shown at *A*. This is mounted, surrounded by several smaller gears *B*, the teeth meshing. All these gears *B* are mounted on a single construction, so that they rotate together. Outside of these pinions *B* is a large gear *C* with internal teeth meshing in the teeth of the smaller gears.

Suppose that *A* is a driving member and is rotating by the power of the motorcycle motor. If the outer ring *C* is free to revolve and the pinions B stand still, the ring C will revolve in the opposite direction from the central gear A and nothing will be driven. The pinions B

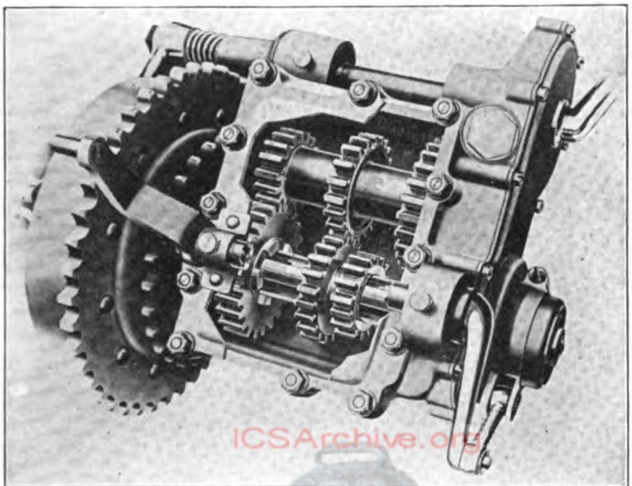

Fig. 38. Harley-Davidson Three-Speed Transmission

are fastened to the rear wheel of the motorcycle so that these stand still when the motorcycle is standing still. If while the gears are rotating on motor power, the outer ring C is held still by means of a

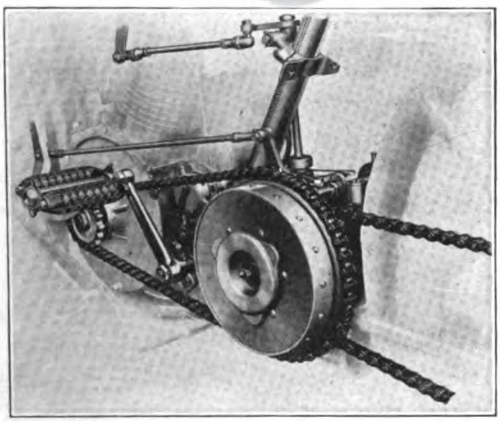

Fig. 39. Method of Mounting Transmission in Harley-Davidson Frame

brake as at E, then the four pinions B will roll between A and C with a sun-and-planet motion at one-half the revolutions of A, about the center of the wheel as a center. This gives low gear with a two-to-one reduction. If the brake E is released and the dog clutch D thrown into engagement, connecting the drive sprocket solidly with the gear A, then the whole planetary mechanism will revolve as a unit *without gears and rotating on high*. That feature has made the planetary gearset popular.

Fig. 36 shows a Harley-Davidson two-speed wheel hub which works on the same principle, except that bevel gears are used.

Two-Speed Sliding Gear. Fig. 37 shows a Dayton sliding-gear two-speed transmission fitted with a multiple-disk clutch shown in section. This clutch is operated by a lever or pedal and, when in engagement, enables the sprocket A to drive through the gear mechanism to the sprocket B, which is the main-drive sprocket. If the small cam ring, shown in the center of the gearset, is moved to the left by a lever, the dogs engage a shaft from A direct to B, so that one is driving on high gear. On releasing the clutch, the cam ring C can be shifted to the right to mesh with the smaller gear on that side, which is driven by the sprocket A. This gear now drives through the two lower back gears, back through the upper left-hand gear to the sprocket B, which now, instead of traveling with A, travels at about half its speed. This is low-gear position. This type of gearset is used on a number of prominent motorcycles, the differences being mainly in details.

Fig. 40. Simple Passenger Attachment for Motorcycles

Three-Speed Sliding. Fig. 38 shows a three-speed gear fitted to the Harley-Davidson and operating on the same principle as the two-speed gears just mentioned. At the extreme left is shown the clutch and the large and small sprockets. The lower shaft to the gearset is the main shaft, and the two gears at the right on this lower shaft slide on keys on the shaft. The shaft is driven by a big sprocket, while the smaller sprocket is fastened to the left-hand gear. If the two sliding gears are shifted to the left, a dog engages them with the left-hand gear, these dogs being clearly seen in the cut. If the gears move to the position shown in the cut the machine is on second speed, driving through the four gears which are in mesh. If the two gears are shifted farther to the right the right-hand one of the two lower gears comes in mesh with the right-hand big gear, and the machine is on its lowest gear ratio. The method of mounting this gearset on the Harley-Davidson is shown in Fig. 39.

A smaller three-speed gearset used on the Indian motor-cycle is shown in Fig. 32 in connection with the disk clutch attached. In this case, a single sliding gear on the principal shaft makes all the connections and gives a progressive gearset of extreme simplicity. A gearset is a necessity on motorcycles intended for passenger use.

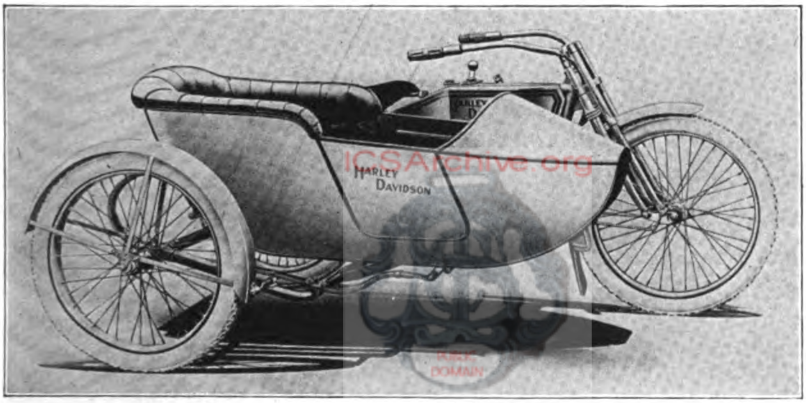

Fig. 41. Harley-Davidson Side Car
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

Passenger Attachments. The motorcycle has become so popular a vehicle that owners wish to take their friends with them. Hence has come about the popularity of passenger attachments. Fig. 40 shows the simplest type of passenger attachment for motorcycles, this being an extra seat fastening at the back of the driver's seat, making the machine into a tandem vehicle. Many thousands of these are in use in America. While at first they were viewed with a certain degree of contempt by the automobilist, they have become accepted as a proper means of conveyance. Many who are not possessors of this attachment fit a heavy cushion to the luggage carrier at the rear and mount a passenger on this.

Seeking for more dignity in a passenger attachment, motorcycle riders have adopted sidecars as a solution, as shown in Fig. 41. Separate upholstered-body constructions are fitted with an extra wheel, all of which attaches to the side of an ordinary motorcycle so that the passenger may be carried in a comfortable conveyance alongside the driver. Sidecars are becoming more popular every year as the length of good roads is increasing. Their chief disadvantage is the side strain caused by the pull of the third wheel.

OPERATION OF MOTORCYCLES

The Motor. Obviously the most important part of a motorcycle is the prime mover, and in order to handle his mount intelligently, it is well for the rider to understand something about the principle upon which the motor operates. The motor, as previously stated, usually consists of a four-cycle type of single- or twin-cylinder gasoline engine or explosion motor. The explosive mixture, which furnishes the source of power, consists of vaporized gasoline and air combined in the proper proportions through the action of the carbureter. This mixture is drawn into the cylinder of the engine by the suction of the piston in its downstroke. The upstroke then compresses the mixture. Just at the completion of the upstroke this charge of compressed gas is ignited by an electric spark, which causes it to explode, thereby forcing the piston downward. Then, when the piston comes up again the exhaust valve opens and the burnt charge is forced out. It is thus seen that there are four distinct actions which take place, namely, admission, compression, explosion, and exhaust, and as these operations are accomplished in four strokes of the engine, such a motor is called a four-cycle engine.

When the motor is in good working order it requires practically no attention other than to supply it with fuel and keep it properly lubricated. When any serious trouble occurs, it is a safe plan to take the machine to an expert and have it properly repaired, and this will usually prove the cheapest way in the end. Some of the more common sources of trouble may, however, be located by the use of a little common-sense and judgment. It is of fundamental importance that the motor should be securely attached to its base, as otherwise it may be twisted around by the belt or chain, thus throwing it out of alignment. It is, therefore, a good plan to go over the motor and its connections, from time to time, tightening up all loose nuts and bolts.

A very common form of trouble is indicated by a knock or pound, which will ordinarily be found to be due either to lost motion, or to premature ignition. The pounding, due to lost motion, indicates too much play between parts which have relative motion, and would most commonly be caused by looseness of connecting-rod or crankshaft bearings. Premature ignition, on the other hand, causes pounding of a sharper and more metallic sound, and may be due either to the fact that the spark is advanced too far, or to overheating. In some cases it may also be caused by carbon deposits in the cylinder, which become incandescent and cause premature ignition of the gas in this manner. A good way to locate a knock is by the sense of sound, which may be assisted by putting a piece of metal, such as a heavy wire, against different parts of the motor, while holding the other end between the teeth. The source of the trouble will then be indicated by excessive vibration as the wire approaches it.

The forming of carbon in the cylinder is objectionable since it causes overheating and loss of power, as well as premature ignition. This can be avoided by occasionally injecting into the cylinders a small quantity of kerosene while the motor is warm, turning the engine over a few times, and leaving it thus over night. The kerosene should then be forced out by turning over the motor. The foul oil should then be drained from the crankcase and replaced with fresh oil.

The leakage of gases from the cylinder, escaping past the pistons, due either to wear in the cylinder or piston rings, is likely to cause overheating of the upper part of the crankcase. When it is found difficult to turn the engine over, the cause is probably due to the overheating and consequent binding of the piston.

Valves. In order to obtain the best results from the motor it is important that the valves should be properly seated, and that the springs should be neither too stiff nor too weak. It is somewhat commonly supposed that grinding the valves will prove a cure for almost any of the ills to which the gasoline motor is heir. This is a mistake, and valve grinding should not be resorted to unless it is necessary. The grinding of valves is a comparatively simple process, but should not be carried to excess, as it lowers the valve on its seat, which amounts to the same thing as lengthening the valve stem and preventing the valve from seating properly, thereby causing a difficulty greater than that which the grinding was expected to relieve. In order to grind a valve, a paste should be made from emery and oil. This should be put both on the seat and on the edge of the valve itself. Then the valve should be placed in position and turned slowly in its seat by means of a screwdriver, meanwhile maintaining a steady pressure; while the turning should for the most part be in one direction, an occasional part-turn backward should be taken. During the process care should be exercised to see that the pressure is in a perfectly vertical direction, as otherwise an uneven grinding will result. In order to tell when this process has been continued long enough, and the valve is properly ground, the surface of the valve seat, and the valve, may be coated with smoke from a candle. The valve should be placed carefully in its seat and turned completely around once, and then examined. If the grinding has been properly done a complete, bright ring will be seen all the way around the valve. Breaks in this ring indicate that the grinding should be continued.

Carbureter. The proper action of the carbureter is of vital importance to the smooth operation of the motor, and on this account, when anything goes wrong, it is very common for a beginner to decide at once that the trouble is in the carbureter and begin to tinker with it. As a matter of fact, however, it would be wise for the novice not to attempt any adjustment of the carbureter until he has made a careful study of the type he is using.

The motor should ordinarily start without priming the carbureter, unless it has been standing a long time, or unless the weather is cold. In case it does not start readily, priming may be resorted to, although it should be remembered that over-priming does more harm than good, since the motor then becomes supplied with too rich a mixture, which is as hard to fire as one which is not rich enough. If the gasoline refuses to flow altogether, even after priming, the trouble can sometimes be relieved by blowing into the opening of the gasoline tank. Ordinarily, about the only attention the carbureter requires is an occasional cleaning, the frequency of which depends very largely upon the quality of the fuel used, and the care with which it is strained. In case the spray nozzle becomes so seriously choked that blowing into the tank will not relieve it, the difficulty can usually be overcome by holding the finger on the priming pin until the carbureter floods, while simultaneously racing the motor.

The adjustment of the carbureter can be determined by observing the exhaust. If the mixture is too rich, black smoke and red flame will appear. If it is not rich enough it will be indicated by yellow flame, while normal conditions are indicated by blue flame. An important point to bear in mind is that the proper mixture varies with atmospheric conditions, and a richer mixture is required in cold or damp weather than when it is hot or dry.

Ignition. In connection with the ignition system, it is necessary to be sure that all connections are clean and firmly made, and that the insulation is sound throughout, and in case of battery ignition it is, of course, necessary to see that the batteries are in good condition. In order to get the best results from the batteries it is well to have an ammeter with which to test them. New batteries should test from 15 to 18 amperes and about 1.5 volts. When a battery has run down to 4 or 5 amperes it can no longer be depended upon and should be thrown out. Each cell should be tested separately, and it is never well to connect an old cell with new ones, as the old cell tends to reduce the life of the new ones. The terminals of a battery should never be short-circuited by testing directly across them with a wire or screwdriver, as a battery can be completely exhausted in this way in a short time. It is well to go over all joints and connections periodically, making a careful examination to see that all binding posts and set screws are tight, and that all points of electrical contact are bright and clean. The insulation should also be examined from time to time, looking not only for spots where the insulation has been worn away by chafing, but also for any places where it has become saturated with oil. Inspection of this sort is particularly important in the secondary winding, where the insulation must be much more perfect on account of the high voltage employed than in the case of the low-tension primary wiring. In regard to the contact breaker, it is important to see that it is properly adjusted, and that the platinum tip is clean and bright.

A common cause of trouble in the ignition system is due to soot on the points of the spark plug. The spark plug should accordingly be removed occasionally and the points cleaned.

The magneto is very seldom the cause of trouble, and, under ordinary conditions, should not be tampered with by an inexperienced person. One common source of trouble with the magneto, which can easily be relieved, is due to the binding of the carbon brush in its holder, thereby preventing proper contact between the brush and the commutator. The same thing will result if the spring which holds the brush against the commutator becomes weak or is broken.

Lubrication. The matter of lubrication has already been mentioned, but it is so vital to the satisfactory operation and to the life of a motorcycle that it will bear repetition. The oiling should not be a perfunctory operation to be taken care of at random, but should be done methodically at intervals depending upon the grade of oil used. Of course, it is possible to go to extremes and oil too frequently, but too much oil is preferable to too little.

Only the best grade of oils should be used, as the difference in cost is only slight and a poor oil is sure to cause trouble. The manufacturers are always glad to give advice as to the kind and grade of oil best suited to their make of motor, and one would do well to be guided by such advice, since no one knows a machine so well as the maker, and it is to his interest as well that the machine give a good account of itself.

Tires. The principal point to be borne in mind in connection with the tires is that they should be kept pumped up hard, as riding on soft tires is likely to injure both the casing and inner tube, as well as requiring more power to drive the machine. A tire pump should always be carried when on the road and the condition of the tires examined frequently for any indication of softness.

A spare inner tube, sprinkled with tire powder and carefully folded and enclosed in a separate package, should be carried along, for replacement in case of a puncture or a blow-out. In addition, a tire-repair outfit should always form part of the rider's equipment, for making quick repairs on the road.

In replacing tires with metal tire tools, care should be taken not to chip the enamel off the rim, as this will cause it to rust and the rust will in turn injure the tires. On this account it is well to paint the rims occasionally as a guard against rust. Grease and oil are very injurious to rubber, and should never be allowed to remain on the tires, but should be washed off at once with gasoline.

Control. The speed and amount of power developed by a motorcycle depend upon two factors: the quantity of gas supplied to the motor and the time at which the spark occurs with relation to the position of the piston in its travel back and for thin the cylinder.

The devices for controlling these two factors or for regulating the *throttle* and *spark* should be conveniently located so that they can be manipulated instantly while at the same time keeping the hands in position upon the handlebars.

Nearly all the earlier machines were equipped with the *twist-grip type of control,* in which twisting one grip varies the position of the throttle, and the other the position of the spark. This type of control has the disadvantage that, in heavy going, where a firm hold on the handlebars is necessary, the rider is in danger of twisting one or both of the grips unintentionally, thereby varying the position of the throttle or spark at the wrong time. This objection is overcome to a large extent by having the twist grip located in front of secondary grips, which are rigidly attached to the handlebars.

Handlebar or lever control is rapidly coming into favor, this consisting of levers placed in front of the grips with rod and knuckle joints or wire cable leading therefrom to the carbureter and spark mechanism. Cable seems to be the more satisfactory, as with its use there is no lost motion, as in case of the rod and knuckle-joint system. An advantage of the lever type of control is that the exact position of the levers can be seen at a glance.

Whatever the type of control, the rider should so accustom himself to its manipulation that he can, in case of emergency, throw off the power and apply the brakes instantly. In fact, these operations should be so familiar as to become automatic.

General Instructions. Before starting out, the rider should be sure that he has an ample supply of gasoline and oil in the tanks, never using anything but strained gasoline. The machine should be well oiled and the tires examined to see if they have sufficient air. All bolts, nuts, and screws should be gone over, and tightened if necessary. The wiring should be examined for loose connections or breaks in the insulation, and the batteries should be tested with an ammeter. Any excessive slack in belt or chain should be taken up. If these matters are attended to systematically before starting out, many an awkward and embarrassing delay on the road will be avoided.

The matter of physical comfort while on the road is of importance, and in order that the greatest degree of comfort be obtained the saddle should be placed fairly low and not too far back. The handlebars should be high enough to avoid the necessity of stretching or bending forward, and the bars should be so shaped that the hands rest upon them in a position which is easy upon the wrists.

The rider should become so familiar with his machine that he can tell when it is running properly by the sound. Any unusual noise is a sure indication of something wrong, and the machine should be stopped instantly and examined for the cause. It is probable that the trouble can be located and repaired in a moment if attended to at once, but if allowed to go on it might easily develop into something which would cause serious injury to the machine. The motor should not be run for long periods of time on the stand and should never be allowed to race unnecessarily.

No definite rules can be given for governing the rider's conduct when on the road, other than that which would be dictated by common-sense, and a proper consideration for the rights of other vehicles, and particularly for pedestrians, and one must, of course, take into consideration the rules in regard to speed limit which obtain in the particular locality through which he is driving. The machine should be kept under control at all times, so that it can be brought to a stop almost instantly in case of any sudden obstruction in the traffic, and it is well not to drive too close to the vehicle ahead, as this may stop suddenly, while the one behind you does not stop, thus causing an awkward, if not serious, situation. In turning corners, or passing other vehicles, a wide curve should always be taken in order to avoid the tendency to skid, which arises from taking sharp turns at high speed. Always slow up when turning a corner.

One of the principal causes which has brought the motorcycle into disrepute is the excessive noise caused by riders opening the muffler cut-out unnecessarily. There are times when it is necessary to do this, but the use of the cut-out should never be carried to excess.

When starting on a trip which will keep the rider out after dark, the lighting system should be examined to see that it is in good condition, as it is required that the motorcyclist show a head light and a tail light at all times after dusk sets in.

Upon returning from a ride the motorcycle should always be cleaned before putting it away, or at least as soon as possible thereafter. The longer the cleaning process is delayed, the more difficult an operation does it become. Mud which is allowed to cake upon the cooling flanges of the motor cuts off the circulation of the air, and causes overheating. Oil running down from the bearings collects dirt, which is sure to work back into the bearings sooner or later and cause trouble, while the presence of mud and moisture on the machine causes rust, which soon injures the appearance of the machine, if it does not do more serious harm. In fact, cleanliness at all times, and in connection with all parts of the machine, is a golden rule of motorcycling, and is an investment of time which will give large returns in the satisfactory operation and life of the machine.

CYCLECARS

HISTORY AND DEVELOPMENT

Barbeau Cyclecar. About 1912 a motor development started in England known as the cyclecar movement. This came originally from a peculiar type of motor vehicle built in France in 1910 by M. Barbeau of Paris, France, who built up a motorcar on a 36-inch

Fig. 42. Prevot on Cyclecar Bedelia, Equipped with Twin V-Type Water-Cooled Motor
Courtesy of Motor Age

gage or track, seating two persons tandem-fashion on hammock seats, Fig. 42. He derived power for the propulsion of the machine from a motorcycle motor, Fig. 43, and carried this power by chain to a countershaft amidships, Fig. 44, and finally to the rear wheels by V-shaped rubber belts, as seen in Fig. 42.

Popularity in England. The units composing this vehicle came from the motorcycle, and the Bedelia, as the machine was called, was hailed in England a year later as the beginning of a big motor movement. England built a number of cars on this line, and all--as did the original—showed a surprising comfort and speed and were quite reliable though very flimsily constructed. The Bedelia

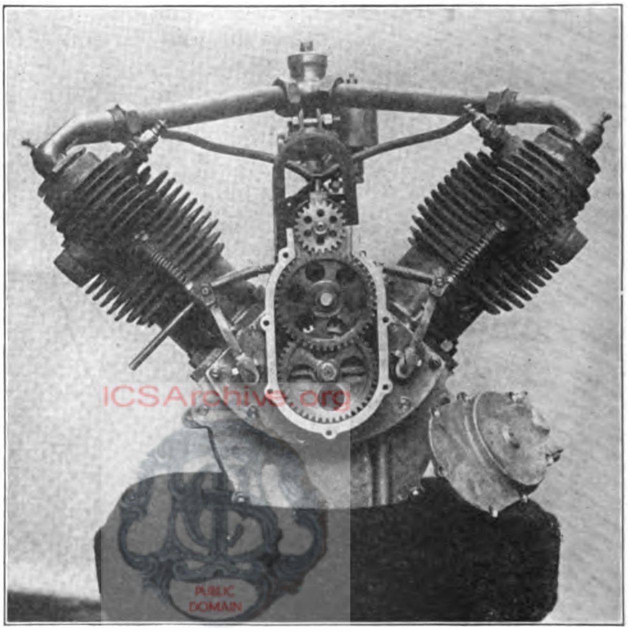

Fig. 43. Barbeau Cyclecar Motor
Courtesy of Motor Age

weighed about 750 pounds, although a 400-pound weight was claimed and with only an eight-horsepower motor averaged over 38 miles an hour in a 138-mile road race in France.

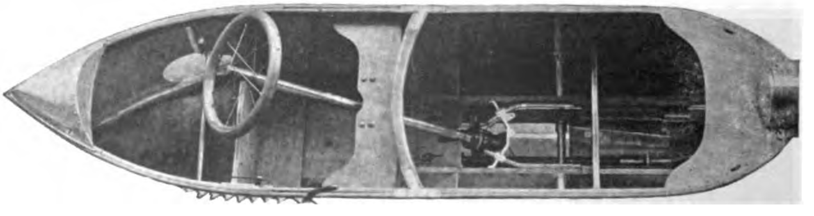

Fig. 44. Plan View of Bedelia Cyclecar Body, Showing Chain Transmission from Engine to Countershaft
Courtesy of Motor Age

The ability of any car to hold the road at speed is due largely to the ratio of the tread to the wheelbase. By using a narrow tread, the Bedelia was able to hold the road surprisingly well, and, having less leverage from the center of gravity, it used less motor power in overcoming road obstructions. This was the secret of the cyclecar's road speed with small motors. Using the belt drive to the rear, the rear axles of these cars were very light, which made the riding very easy. Road bumps were felt surprisingly little for such light cars.

Development in America. America was not slow in following the lead of England, as England was quick to follow France. While England, however, was passing from the cyclecar to the light car by a process of evolution, the cyclecar was at its height of favor in America. A hundred cyclecar designers sprang up in all parts of the country and hosts of machines were announced. Only ten or twelve of these, however, seriously materialized, and, on account of the haste with which they had been put on the market and the little time spent on development work, lasted but a short while.

The factories that got started quickly found that the public was interested and willing to watch the other fellow buy, but did not want to risk money on experiments. Thus the boom was submerged for a time in the growth of the light car, but it is bound to return in a different form—perhaps through the intrinsic value of the idea. The eventual cyclecar, however, will probably take the greater part of its practice from the motorcar, not the motorcycle.

Motorcycle motors were not suited to the work. They were too light and had too little flywheel. They were too noisy and too hard to start and, above all, cost more than a regular four-cylinder motor. This last was the real vital reason for the discarding of the cyclecar idea in America—the abnormally high cost set on V-type motors.

Passing of the Cyclecar into the Light Car. The cyclecar under that name has been practically dropped as a manufacturing proposition, but in the name of the light-car movement the spirit of cyclecar work is being continued. Firms building cyclecars found they had hit upon a remarkable road quality and, in the light car, they have tried to keep the road principles of the cyclecar and to add the reliable and salable mechanism of the motorcar to the light weight. The Scripps-Booth Company went even further and, after a year's experiment with the cyclecar—built for minimum cost, jumped to the opposite extreme and built the most expensively luxurious car they knew how to build for extremely light weight on the belief that the road work of which the light weight was capable was worth better material and workmanship than had been given to the cyclecar or even to the light car. In France this idea has been worked out in the Baby Peugeot, a diminutive model of the famous Peugeot racing cars. This is being marketed in America with some slight success. The results of the cyclecar boom are apparent in the design of every big car that is now striving to lessen weight and add to comfort, this desire being, to a certain extent, a result of cyclecar publicity.

TYPES OF CYCLECARS

Three Characteristic Types. The cyclecar movement brought out three types of vehicles: three-wheelers, such as the Cyclonette,

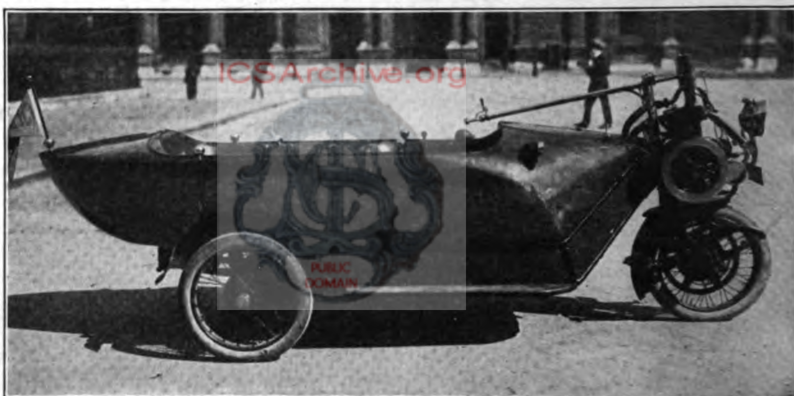

Fig. 45. Three-Wheel Cyclonette with Pure Boat Type Body
Courtesy of Motor Age

Fig. 45; four-wheeled cars built for minimum weight and extreme cheapness; and miniature motorcars built from the cheap-construction angle. The whole idea of the cyclecar movement was to produce the cheapest possible motor vehicle.

THREE-WHEELED TYPE

Morgan (English). Growing up from the motorcycle and the sidecar, a three-wheeled type of cyclecar was developed abroad, this being best represented by the Morgan. This machine has two wheels in front and a single wheel at the rear. It is fitted with a tubular frame and leaf springs and mounts a body seating two passengers side-by-side, and has a sloping hood in front. The

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Cricket. The Cricket cyclecar of Detroit was the most unusual of any built. This consisted practically of two motorcycle frames set side-by-side, with a flexible connecting frame which supported a two-seating body between them. This body was roomy and seated the passengers side by side, Fig. 58. The motor was of the motorcycle type and fitted on the right-hand running board, from which a chain carried the power to a gearbox just back of the motor. From this gearbox a single belt took the drive to a single rear wheel, so that all the power was from this side. This car was sold in small quantities and was used for some time in delivery work when fitted with a package body.

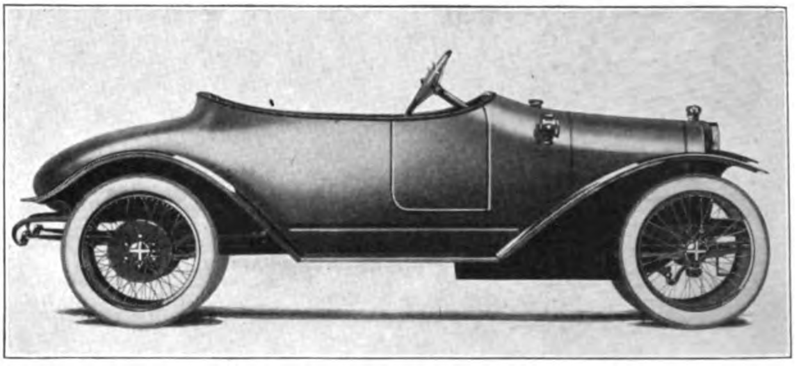
TREAD QUESTION A CYCLECAR DEVELOPMENT

New Facts Learned from Cyclecar Movement. A particular subject of discussion in connection with cyclecars was that of tread. Most of these were of 36-inch width, and the great surprise of the cyclecar movement was the wonderful stability and extreme comfort on rough roads which these little cars showed. If no other lesson was learned from the cyclecar movement than that light weight can be made a factor of comfort, and that unsprung weight is the thing to steer clear of, then the cyclecar movement was well worth the effort which was put forth in its preliminary development. The influence of the riding quality which was discovered in the cyclecar was felt all through the motorcar movement and has had a beneficial influence upon light-weight automobile design.

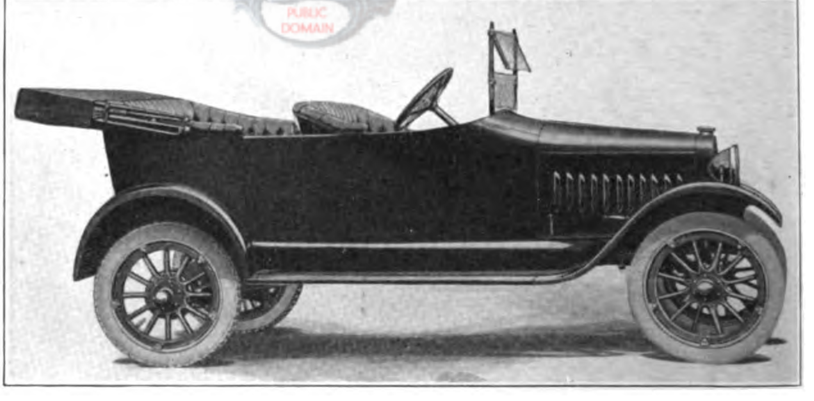
Cyclecar Merged into Light Car. The cyclecar movement has developed abroad into the light-car movement, and some dozens of makes have been developed abroad on a narrow tread, which have been wonderfully successful in reliability and speed. These cars, weighing around 700 pounds, have made speeds up to 80 miles per hour with diminutive four-cylinder motors and have made a reliability showing equal to that of the best big cars. America has not been so quick to take to narrow tread on account of its road conditions, but enough has been done to prove it to be a practical proposition for any kind of road where standard tread would do, although far from advisable from the sales standpoint. The narrow tread was discarded by a number of firms entirely for sales reasons, as the standard tread was easier to sell, and selling was the basis of success.

The narrow tread undoubtedly will appear again in more refined and better developed forms and in a great variety of machines, first for city use in coupés, runabouts, and similar cars; and, as drivers learn the advantages of narrow tread for country use, the field may broaden to include other types of light vehicles.

In designing these narrow-tread cars it is thought advisable by most engineers to make the tread as narrow as possible consistent with stability, as the narrower the car the more nearly it can travel in a direct line without interference from road shocks on one wheel or the other; also less power is consumed in side thrusts and more can be done with the small motor power. The narrow tread is hardly practicable, however, in cars weighing much over 1200 pounds, as in heavy weights with equivalent motor power to move them on hills, there is plenty of power to take care of the standard tread. The future narrow-tread car probably will not weigh over 800 pounds, and will carry two passengers in staggered seats.



BRISCOE THREE-PASSENGER "CLOVERLEAF" LIGHT CAR ROADSTER
Courtesy of Briscoe Motor Company, Jackson, Michigan



SAXON SIX-CYLINDER LIGHT CAR
Courtesy of Saxon Motor Company, Detroit, Michigan

LIGHT CARS

INTRODUCTION

Place and General Classification. Light cars as a class are such a comparatively new development in motor-vehicle practice in America, that the boundary lines between the cyclecar on the one hand and the smaller sizes of automobiles proper on the other are not very sharply drawn as yet in this country. England has drawn arbitrary lines which define the various classes, and the American Automobile Association, the governing body in automobile contests on this side, has adopted a similar definition for racing purposes. This is based on the piston displacement or cylinder volume of the motor, and classes as cyclecars, those with motors of less than 71 cubic inches displacement; as light cars, those having motors whose displacement is between 71 and 100 cubic inches; and as small cars, those whose motors have a cylinder volume between 101 and 125 cubic inches.

Aside from contest purposes, however, light cars may be taken to include both the light cars and the small cars as defined under the A. A. A. classifications. It is evident that the mere factor of weight is not the deciding one in this definition, but small displacement presupposes low weight, if the engine is to propel the car satisfactorily. The weight limit may be placed roughly at 1800 pounds as a maximum, as few, if any, of the light cars exceed this even with full equipment.

Early History of Development. All early gasoline automobiles were light cars, both as to cylinder volume and as to car weight, but they were notoriously underpowered even for the slightly-strengthened buggies in which the engines were installed. As the gasoline motor was so new, knowledge and experience were lacking to make the same size of motor produce more power, so the only alternative was to use bigger motors. The cylinders were made larger and increased in number from the original one-cylinder to two, to four, to six, to eight. As the motors increased in weight, it became necessary to increase the strength and weight of the transmission and running gear in proportion, so that pleasure cars weighing three tons were not uncommon.

Motorists found driving increasingly expensive, as tire, fuel, oil, and repair costs grew in proportion. The fuel bill was not much of a factor until a few years ago when the price of gasoline commenced to mount. But it was in Europe that the expensiveness of large cars began to make itself felt. Most European countries imposed an automobile tax based on the power of the motor and the power was calculated by a formula in which the square of the bore entered as the chief factor. Motorists in England, France, and Germany figured that by using motors of one-half the bore, the tax would be reduced to one-fourth its former amount. As these taxes were comparatively heavy, such reduction was an item of moment. Then, too, a heavy impost duty was in force on gasoline. so that anything that would reduce the size of the engine meant a double reduction in operating costs.

European engineers took up the problem of increasing the efficiency of the cars and, particularly, the efficiency of the engines, with the result that they produced motors of smaller size which would do the same work, but which could be operated on much less fuel. Along with this, they succeeded in reducing the weight of the car as a whole without sacrificing strength, and increased the efficiency of the transmitting mechanisms so that the motors were not called upon to do so much work in producing the same results on the road. They found also that by proper shaping of the lines of the car, the decrease in wind resistance was such as to permit still smaller motors.

Advent of Cyclecar. Some car builders carried the idea of weight reduction out to the limit in Europe, and the result was the cyclecar, which obtained a decided, if temporary, vogue. This minimum type of car had a distinct appeal on account of its low first cost, operating cost, and its handiness. The narrow tread idea was what made the cyclecar possible, and it was quite applicable to European roads, which were uniformly smooth, and where there is no really standard tread, as we know it here.

Cyclecar Grows to Light Car. Just when the cyclecar movement reached its apex in Europe, American manufacturers took it up, but the popular prejudice against a tread less than the standard 56 inches and the rather disappointing performance of most of the early models gave the industry in America a setback from which it will not recover for some years at least. Manufacturers who did not join in the first rush to put out cyclecars found that, in order to produce satisfactory vehicles, these would have to be somewhat heavier, stronger, more powerful, and therefore, more expensive than the cyclecar. When the designs of these more conservative makers did appear, they had four-cylinder motors, gear transmission, shaft drive, side-by-side seating, and tread either standard or nearly so—in fact, all the earmarks of an automobile as it was generally known, except size, weight, power, and cost; in short, a light car.

Large Car Dwindles to Light Car. At the same time that the light car was growing up from the cyclecar, it was growing down from the large car. The diminution had been in progress for years in Europe, and light cars as we know them had become popular abroad. Big-car makers in America had found it increasingly difficult to market the heavier types in quantities sufficient to make them financially profitable, and for several years the majority of manufacturers had been decreasing the bore and stroke of their engines and the weight of the car as a whole. This was made possible by the advances both in the art which made lighter and more efficient motors possible and in metallurgy, which made possible lighter parts without loss in strength.

The light car, then, is the meeting of the upward growth of the cyclecar and the lightening and making smaller of the large car. The development of the light car was neither as rapid nor as simple as it would seem at first thought. There were difficult problems to be solved before the light car could be either satisfactory to the user or commercially profitable to the maker.

Special Problems. Two of the first problems which presented themselves to the light-car designer were, first, the production of motors of small weight and small fuel consumption which would give adequate power; and second, the accomplishment of easy riding qualities with light construction. Coupled with these were the problems of proper seating arrangement with minimum weight and wind resistance, and along with all this, low first cost, low maintenance cost, and reliability.

CHARACTERISTICS OF ENGINE DESIGN

With very few exceptions, light-car builders have installed power plants developed specially for this service by engine builders.

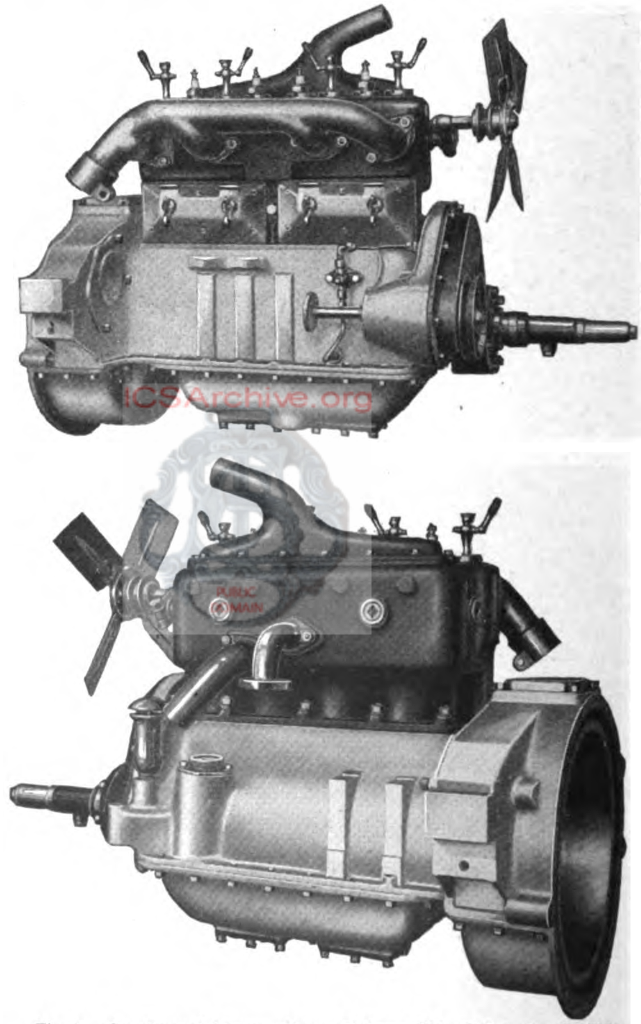


Fig. 1. Continental Motor—Above, Exhaust Side; Below, Intake Side
Courtesy of Continental Motor Manufacturing Company, Detroit, Michigan

The four most widely known of these motors are the Continental, Fig. 1, Sterling, Fig. 2, Perkins, Fig. 3, and Hirschell-Spillman, Fig. 4. Ordinarily, motor, clutch, and gearset are bought as a unit, the three mechanisms being bolted together so that assembly is particularly easy. The Saxon and the Grant four are exceptions to this, having the gearset as a unit with the rear axle, though in the

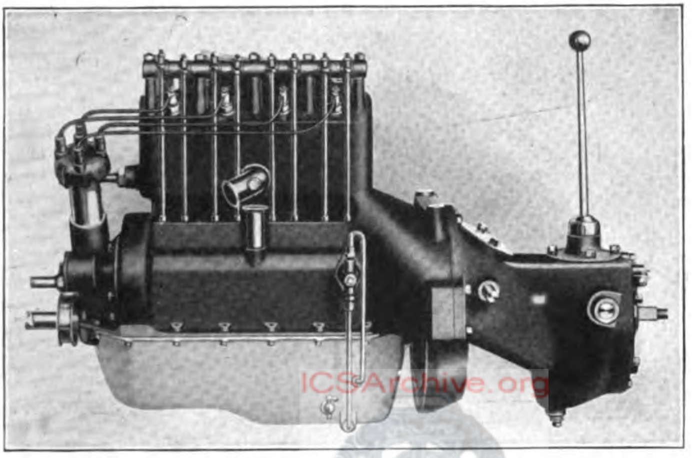


Fig. 2. View of Sterling Motor Showing Valve Operation and Timer Drive
Courtesy of Sterling Motor Company, Detroit, Michigan

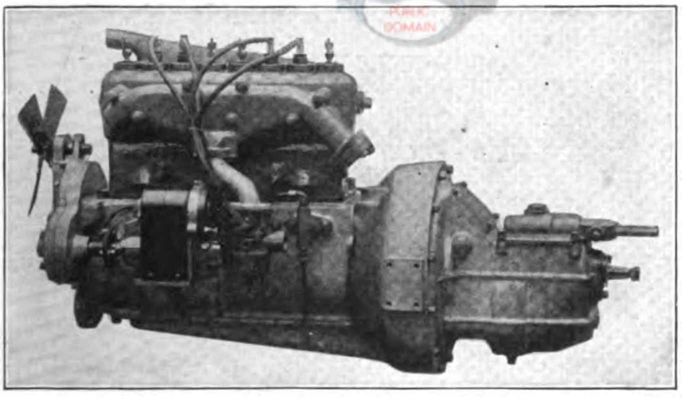


Fig. 3. Intake Side of Perkins Light-Car Motor
Courtesy of Massinick-Phipps Company, Detroit, Michigan

later six-cylinder Grant production, the more conventional arrangement is followed.

High Speed a Requisite. The development of these high-speed engines is the one thing that has made the light car possible. By high-speed engines is meant, motors designed to operate at greater crankshaft speeds than is possible for ordinary motors and which will produce power in proportion to their speed, between very wide

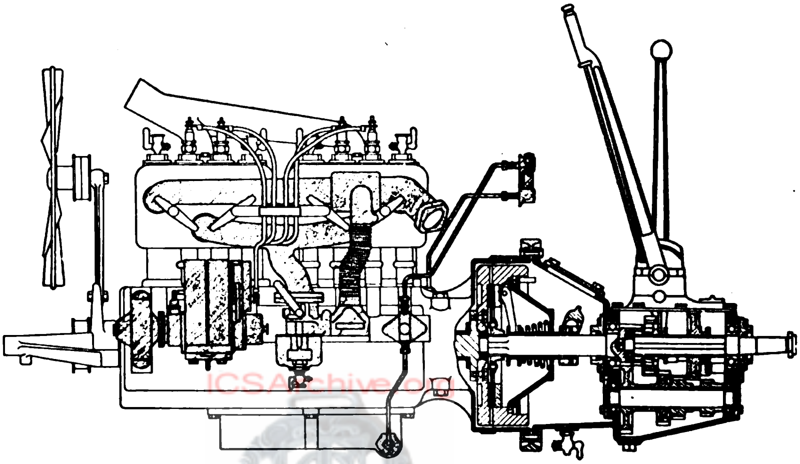


Fig. 4. Sectional View of Light-Car Motor
Courtesy of Golden, Belknap, and Schwartz Company, Detroit, Michigan

limits. Figs. 5 and 6 indicate what is meant by this, Fig. 5 showing the power curve of a typical high-speed light-car motor and Fig. 6 the power curve of the ordinary motor for large cars. It will be

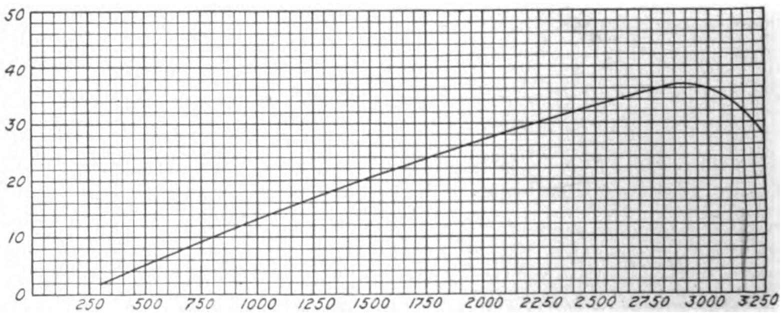


Fig. 5. Power Curve for Typical High-Speed Light-Car Motor

seen that though the cylinder dimensions of the high-speed engine are only half those of the other, nearly the same power is developed at their respective maximum speeds.

A few years ago a piston speed of 1000 feet per minute was considered the highest it was possible to obtain in practice. Today motors are running at three times this piston speed, and the high-speed motor of today is developing twice the power of motors of former years with the same bore and stroke.

A few of the important factors in the design of a high-speed motor for light cars, given in the order of their importance in application to the motor layout, are as follows: (1) balance; (2) lubrication; (3) cylinder design; (4) valve construction; (5) manifold design; (6) weight of reciprocating parts; (7) choice of material; and (8) cylinder dimensions.

Balance. By far the most important item is the balance of the engine. Without proper balancing of the reciprocating parts, high speed is impossible on account of the vibration set up at high crankshaft speeds. Many of the light-car motors run up to 4000 revolutions per minute; that means that each piston changes direction 8000 times every 60 seconds. Unless the weights of all the flying parts are balanced by an equal weight flying in the opposite direction at the same time, racking strains are set up in the whole mechanism.

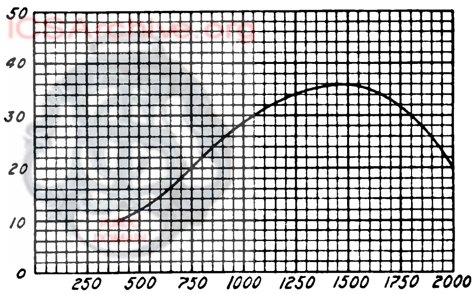


Fig. 6. Power Curve for Typical Motor for Large Cars

Balance of Crankshaft. The most important single member to be balanced is the crankshaft. This must be very rigid in the first place, and fitted with greater bearing surface than would be necessary for lower speeds.

The engine must be short to keep the weight low—probably a block cylinder casting—so that to use more than three bearings is out of the question. In many of the smaller motors now on the market which do not lay claim to high speed, only two bearings are fitted. The entire shaft must be in balance in the high-speed engine, which means that each throw of the crankshaft must be counterweighted. Fig. 7 shows the Harroun method of crankshaft counterweight, the weights performing the function of flywheel as well. Fig. 8 shows the more usual method of counterbalancing which requires a flywheel.

When counterbalancing is not properly done or when the crankshaft is too light, it causes whipping, thus setting up vibration as well as end- and side-thrusts on the bearings. Every shaft has a critical speed at which whipping commences.

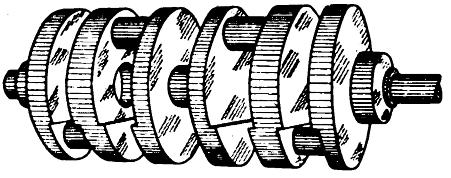


Fig. 7. Diagram Showing Harroun Method of Crankshaft Balancing

Suppose a shaft is running in two plain bearings as in Fig. 9. When it is rotated, the shaft will tend to swing out at its center like a skipping rope, as shown by the dotted lines. If the maximum speed of a crankshaft is to be 3000 revolutions per minute, the shaft must be designed to develop no distortion below that speed. A motor $2\frac{3}{4}$ inches by 4 inches, for instance, does not need a shaft of over $\frac{3}{4}$ inch in diameter to prevent its breaking from the twist, but must be in the neighborhood of 2 inches in diameter to prevent whipping. If the bearings are 36 inches apart, the shaft will have to be $1\frac{3}{4}$ inches in diameter.

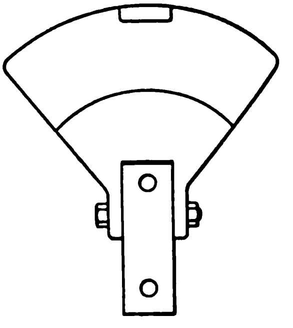


Fig. 8. Standard Counterbalanced Crankshaft

A light crankshaft distorted by speed and the side thrust of the pistons is shown, exaggerated, in Fig. 10, so as to show the effect on the bearings. A light shaft will wear

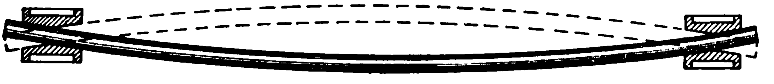


Fig. 9. Diagram Showing Whipping of a Shaft at High Speeds

the ends of the bearings and leave the center high. All the bearing metal that is left is in the center of the bearing, so that on open throttle at low speeds the thrust is too heavy on the small ridge of bearing metal and it burns out. This distortion of the crankshaft is exaggerated in Fig. 11*a*.

Lubrication. A slow-speed motor can work with a comparatively small quantity of oil, but for high speeds every point at which

Fig. 10. Diagram Showing Effect of Whipping on Bearings

two pieces of metal rub together must be flooded with oil. The ordinary practice is to use a gear pump with a fairly high-pressure feed carrying the oil to every part. Usually these pressures do not run more than 15 pounds per square inch, but in some of the European types pressures as high as 30 pounds are not uncommon. Many of the present light-car engines are using a simple circulating splash system, but the pressure feed is conceded the better.

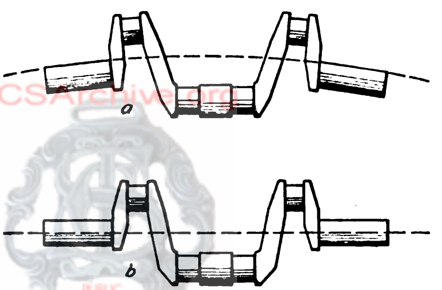


Fig. 11. Diagrams Showing Distortion of Crankshaft; (*a*) Distortion at High Speeds; (*b*) Normal Position

Cylinder and Valve Design. In the design of the cylinders and valve-operating mechanism there are only two types used to any extent, (1) the L-head cylinder with both inlet and exhaust valves on the same side, and (2) the overhead valve design. T-head cylinders are almost unknown in American light-car practice. There are two reasons for this: first, T-head construction is too heavy; and second, too costly for light-car work. The L-head type is popular in light-car practice and has the advantage of being easily silenced. The overhead valve design is theoretically and practically the most efficient, giving the greatest power for each cubic inch of cylinder volume and most miles for each gallon of gasoline. The noise of the valve mechanisms, which has been the retarding feature of this type, has been overcome within the past few years, and overhead valves are being employed extensively in smaller types of motors.

Quick opening and closing of the valves is important in high-speed engines, as well as large valve openings, for if the motor is to run at great speed, the gases must be gotten into and out of the cylinder in rapid-fire order. Along with this is the necessity of ample gas passages from carbureter to inlet valve, on the one hand, and from exhaust valve to muffler, on the other. These also must be of such shape as will least impede the flow of the gases.

Weight of Reciprocating Parts. The weight of the reciprocating parts is really an item of balancing, aside from the effect of the low weight of reciprocating parts in cutting down their inertia. This means extra-light connecting rods and pistons. This is obtained, in the case of the connecting rods, by the use of drop forgings of light steel alloys, such as Ubas steel. Pistons are lightened very frequently by machining them out of magnalium, an aluminum steel alloy, which is lighter and stronger than steel. Connecting rods quite often are tubular, being round steel forgings with the center bored out. With a balanced crankshaft and extra-light connecting rods and pistons—weighed carefully to be sure that they have the same inertia and momentum—there is little to hinder a motor attaining a high rate of speed, if the force of the explosion is sufficient.

Cylinder Dimensions. Engines for light cars necessarily are smaller in cylinder dimensions than those of the larger types of vehicles. In the first place, a certain amount of weight is saved by the use of smaller cylinders and, secondly, there is not the need for high power when there is less tonnage to be transported. Four-cylinder engines are almost universal among light cars, the only cars on the market at this time that do not have four cylinders are the six-cylinder Grant, which weighs only 2200 pounds, and the six-cylinder Saxon.

As a rule, the cylinders vary between $2\frac{1}{2}$- and 3-inch diameter and between $3\frac{1}{4}$- and $4\frac{1}{2}$-inch stroke. The size of cylinder most generally used is $2\frac{3}{4}$-inch bore and 4-inch stroke, though there are some with $2\frac{7}{8}$-inch bore and $4\frac{1}{2}$-inch stroke. These cylinder dimensions are much smaller than the most of us have been accustomed to, but have proved amply powerful and flexible and have surprising economy. The consumption of gasoline usually is less than one gallon for forty miles.

To cite cylinder dimensions of some of the more prominent light cars will show the current practice: Saxon, $2\frac{5}{8}$ by 4 inches;

Grant six, $2\frac{7}{8}$ by 4 inches; Grant four, $2\frac{3}{4}$ by 4 inches; Argo, $2\frac{5}{16}$ by 4 inches; McIntyre, $2\frac{3}{4}$ by $4\frac{1}{2}$ inches; Partin-Palmer, $2\frac{3}{4}$ by 4 inches; Remington, $2\frac{3}{4}$ by 4 inches; Scripps-Booth, $2\frac{7}{8}$ by 4 inches.

There are a few others, such as the Briscoe, Metz, and Pilgrim, which use somewhat larger motors, these being, respectively, $3\frac{1}{8}$ by $5\frac{1}{8}$ inches; $3\frac{3}{4}$ by 4 inches; and $3\frac{1}{4}$ by $4\frac{1}{4}$ inches in size.

Carburetion. Carbureters for light cars present no new problem, providing the design of the motor proper is good. All the standard carbureter makers have special light-car types which differ from their larger models chiefly in size.

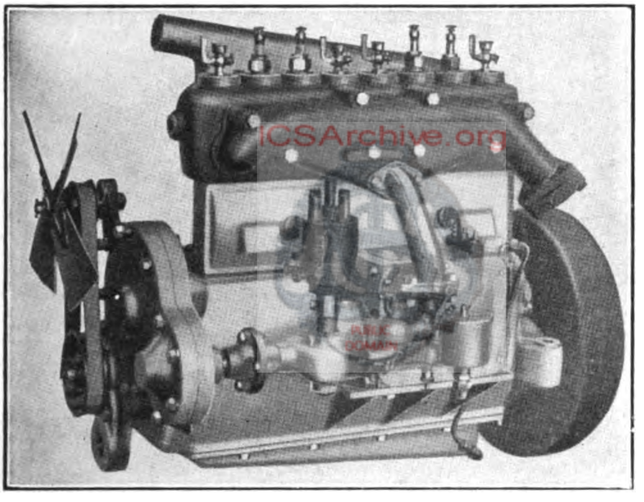


Fig. 12. Partin-Palmer Light-Car Motor with Atwater-Kent Distributor

Ignition. In the field of ignition, the question of simplicity and cost enter into the question and there is a departure from usual practice in the larger type of cars. Instead of the magneto, which is a part of the equipment of most large cars, the great majority of the small-car builders are fitting a special battery system with a distributor which has the feature of automatic spark advance. The Atwater-Kent system is the most popular at this time. With this no spark lever is needed, the apparatus automatically changing the time of spark to the proper point, with changes in engine speed. A typical installation is that of the Partin-Palmer motor, Fig. 12, The Connecticut system also is used to a certain extent. The value of these systems for light cars lies in the ease of installation, comparatively low cost and weight, and the fact that, as most of the cars are marketed with electric lighting or electric cranking and lighting, the storage battery for those features offers an ever-present source of supply.

Cooling. Cooling of the motor is universally by a thermo-siphon flow of water, none of the manufacturers using pump cooling and none using direct air cooling. Thermosiphon cooling has the advantage over pump cooling of being simpler, lighter, and less

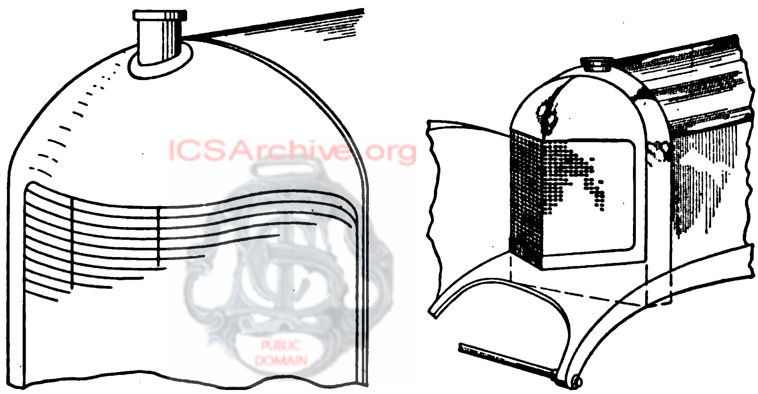


Fig. 13. D-Shaped Radiator of the Grant Light Car and V-Shaped Radiator of the Scripps-Booth Light Car

costly. Radiators frequently are pointed or rounded, for the sake of appearance and to give more space under the hood, and to cut down wind resistance. The rounded radiator of the Grant and the pointed one of the Scripps-Booth are shown in Fig. 13.

CHASSIS AND BODY FEATURES

Transmission. *Cyclecar Transmission Not Adequate.* When light cars began to supplant the cyclecar, designers were influenced somewhat by the practice used in the small vehicles and many of the first light cars to be introduced show cyclecar earmarks. It was learned in the early stages that the two-cylinder air-cooled motor would not do, but that good results could be obtained with a four-cylinder water-cooled motor. But it took a longer period for designers to learn that the driving means from the motor to the rear wheels, as used in the cyclecars, was not the thing for the light cars.

Clutch, Sliding Gearset, and Shaft. Many of the pioneers attempted to market light cars with belt or chain drive and friction sets of cyclecar construction. A few employed planetary gearsets, but as developments continued, the field using these arrangements gradually dwindled to a few and the present cars in nearly every instance use cone or disk clutch, sliding gearset, and shaft to a live rear axle. The dominating arrangement is a unit power plant consisting of a four-cylinder L-head motor, cone or disk clutch, and three-speed selective gearset driving by an open shaft properly jointed to a bevel gear differential. Amidships gearsets are not used to any extent, but the constructions offered are showing excellent results.

Unit Power Plant. The unit power plant forms a cheaply-made compact simple-appearing system and is used by Scripps-Booth, Tiger, Kearns, Princess, Herreshoff, Briscoe, and others. All of these mentioned use sliding-gear transmissions. In the class using motor and clutch as a unit and the gearset on the rear axle are: Grant, Saxon, Trumbull, Woods, and Partin-Palmer. The only friction-driven light car of note is the Metz. Another car using an unusual gearset is the Coey, which employs a two-speed planetary.

Unconventional Designs. While little of radical design has appeared in clutches, pioneers have come in with unconventional gearset and shaft construction. The only light car to use an automatic gearshift for the gearset is the Remington. The first user of a hollow drive shaft is the Scripps-Booth. The latter construction tends toward lightness and, in experimental cars, is being carried to the rear axle shafts.

Axles and Springs. *Axle Weight a Factor of Light-Car Springing.* When the light car came to be a popular vehicle, the easy riding obtained was a surprise even to some of the designers. It was found that these vehicles could go over country roads at a much greater speed than some of the more expensive heavy cars and at the same time give greater comfort for the passengers and with less detrimental effect upon the car mechanisms.

These characteristics are the result of the study of springing and axle weight. The first light-car designers naturally attempted to use heavy-car design on a small car and found that much cheaper construction could be used with far better results.

Most of the hard riding experienced in vehicles is the result of the wheels leaving the ground when a slight obstruction is met and the constant rising and falling of the wheels causes shocks to be delivered through the car to the passengers. When a vehicle strikes a bump, the tire absorbs some of the shock and the rest is reduced in a period of time by the springs, so that when it reaches the passengers it has been decreased considerably. The small bumps are taken entirely by the tires because they wrap around the small obstacles. The springs take those shocks which the tires are unable to absorb wholly. But the spring does not absorb all the shock. The springs merely increase the time element of the shock, sending it to the car occupants in the form of a series of cushioned blows.

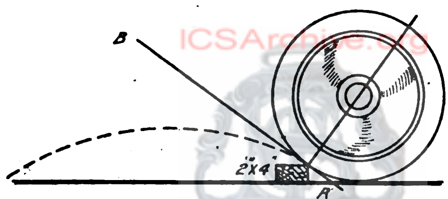


Fig. 14. Diagram Showing Lines of Resultant Spring Stresses in Passing over Obstruction

In striking a bump, as shown in Fig. 14, the entire axle is raised from the ground with the tire, and, since the vehicle is moving forward, the force of inertia tends to keep the axle moving upward in the direction of the line AB, coming to rest when the momentum of the axle has reached zero. The curved line shows the path the wheel would take if there were no force to bring it down immediately after the bump is struck. The heavier the axle and all its fittings, the greater will be the work required to bring it to the ground. The downward pressure is determined largely by the spring unit of deflection and should the deflection be 200 pounds per inch of movement, the wheels will strike the ground sooner than if the deflection is 100 pounds—provided, of course, the axle weight is the same in both cases. This is true because it takes a longer time for the spring with 100-pound deflection to overcome axle momentum. With the 100-pound spring, the axle would rise twice as high off the ground as with the 200-pound one. With the 200-pound spring the passengers are given a blow of 200 pounds for a certain length of time and with the other, a 100-pound blow during twice that period.

Spring Construction. The lighter the axle, the lighter the spring and the sooner the load is brought back to the ground and, consequently, the less shock is imparted to the passengers. The theoretically perfect spring consists of but one leaf, which obviously is more resilient than one of many leaves. With light axles, light springs can be used.

In light-car practice, the front springs usually are semi-elliptics and rather long. In the rear semi-elliptic, three-quarter elliptic, full elliptic, and cantilevers are employed. The latter type is coming to be the standard construction because of its rebound checking qualities and also because it allows of certain advantageous construction with regard to the clearance. The quarter-elliptic springs are sometimes called the semi-cantilever and, while having but few adherents at present, are gaining rapidly. This type requires permanent fastenings at one end, as shown in Fig. 15, and shackles at the other. Axle movement then becomes more pronounced. However, the type shown gives very easy riding with little shock from rebound.

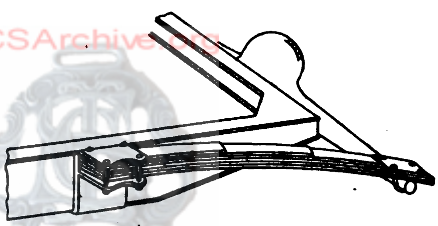


Fig. 15. Diagram of Semi-Cantilever Spring

Easy Riding Depends Upon Ratio of Unsprung to Sprung Weight. Comfort depends largely upon the ratio between the unsprung and the sprung weight or, in other words, the weight above and below the springs. When riding on rough roads, a car with a heavy rear axle instead of having the wheels remain on the ground, would proceed by a series of jumps, causing loss of power and discomfort for the passengers. In the light car, the axles are of light construction and the wheels stick to the road; the springs can be made light and easy riding. The light-axle construction has been helped along considerably not only by the use of pressed steel for the housing but also by the fitting of gearless differentials in the wheels. This eliminates four or more differential gears and permits of lighter bearings being used.

To illustrate that the minimum of unsprung weight is a determining factor in comfort, let us take a 50-pound weight, shown in Fig. 16, to represent the sprung weight of a car; attached to this weight by a stout spring is another weight of 5 pounds, representing the unsprung weight of the car. If the 5-pound weight is struck, so that the spring is compressed one inch, the 50-pound weight will, when the spring reaction takes place, kick or move upward 0.1 inch. The 0.1 is the ratio between the two weights.

Now if the upper weight, or that representing the sprung weight of the car, is increased to 100 pounds, so that the ratio becomes 20 to 1, the rebound of the spring after a 1-inch compression will be 0.05 inch. In light-car construction or in any construction, in fact, the higher ratio is obtained by removing weight from under the springs instead of adding it above them. It is clear from the above that an exceedingly light car, weighing possibly no more than 800 or even 700 pounds, can be as easy riding as a heavy vehicle, provided the sprung and unsprung weights are properly proportioned. It is quite feasible also to so construct a very heavy car as to make it decidedly disagreeable to ride in, simply by causing the ratio of weights to be low.

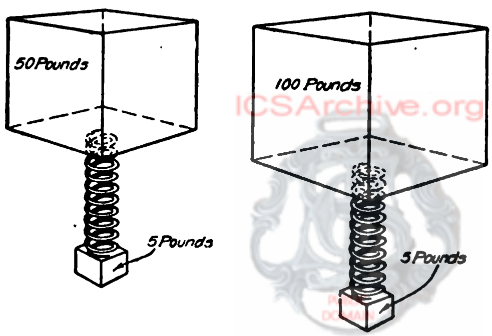


Fig. 16. Diagrams Showing the Effect of Changing the Ratio of Sprung to Unsprung Weight

Rear-Axle Gearset. In some light cars, use is made of a rear-axle gearset. In cars such as this, the designers have taken particular pains to use the lightest of parts in the construction and, while the weight is slightly greater than that of the ordinary rear axle, the cars are giving excellent results.

In the matter of rear-axle gears, the bevel type seems to have taken a firm hold. Nearly all of the American light cars use bevel gears, while a few abroad have fitted worm gears. The Chatter Lea, an English light car, uses an overhead worm construction. While the worm gear has its advantages as regards quietness, it is costly for light-car use, because it must be well made to stand up and requires expensive thrust bearings. However, one great advantage of the worm drive for light-car use is that almost any suitable gear reduction may be obtained without having a noisy set.

With the bevels, when a ratio much higher than 4 to 1 is used, the gears will become noisy in a short while.

Differential Types. Only a few makers are using the gearless type of differential. In the bevel drive there is unequal differential action, because of the inequality in resistance of the road surface. One wheel may be on slippery ground and the other on hard dry ground, causing the former wheel to slip around and only the latter to gain traction to propel the car. With the road surface determining the rear wheel thrust, the tendency to skid is increased. Light cars going at speed will attempt to follow a winding course instead of a straight one.

Deficiencies in the bevel drive, while known, are not taken as seriously in America as they have been abroad. The gearless type of differential, which now is used in several makes, including Kearns, Coey, and a few others, allows both wheels to gain traction regardless of the road surface, giving differential action only on turns.

Wheelbase-Tread Ratio. Another factor which has made the light car possible is the application of the wheelbase-tread ratio, a factor which has been given little consideration in large-car practice but which is a very important point in light-car design. Wheelbase-tread ratio means the ratio of the distance between the front and the rear axles to the distance between the ground contact points of the wheels in either axle. The standard tread is 56 inches, but some light cars which are comparatively short in wheelbase are using treads as narrow as 36 or 44 inches. A car with a high wheelbase-tread ratio is considered by engineers to be more efficient on the road than one with a lower ratio.

To illustrate the principle, let us take the diagram, Fig. 17, representing a car in which the center of gravity is at C. When the wheel W strikes the road obstruction A, the line of shock can be expressed as AB. The thrust of the vehicle forward is shown by CB, acting from the center of weight C. CB then represents the forward thrust and AC the side thrust. The force AB is that which tends to turn the car around, with C as a center. The car's ability to keep a straight course when riding on rough roads or striking a bump is expressible by the proportion $BC \div AC$.

A car with a short wheelbase on meeting resistance, such as sand or soft mud in which one wheel only is struck, will start to spin, and it is a difficult matter to keep going at any speed in a straight course; while, on the other hand, a car with a long wheelbase probably will be managed easily. The point C is a variable with the wheelbase of the car and moves back or away from the front wheels with an increase in wheelbase and forward with a decrease.

The farther back the point C moves, the smaller will be the ratio $BC \div AC$, assuming the same tread; and the farther forward C moves, the greater the ratio. The smaller the ratio, the less the amount of energy necessary to overcome the road obstruction; and similarly, the greater the ratio, the more momentum required.

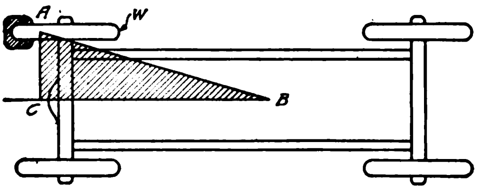


Fig. 17. Diagram Showing Method of Calculating Wheelbase-Tread Ratio

While it is possible to obtain a small ratio by increasing the wheelbase, this dimension has a limit for many other reasons aside from mere appearance. A car of 180-inch wheelbase would not be practical, yet one with such a dimension and 56-inch tread would give a 3 to 1 ratio. The same effect can be had with a car of 36-inch tread and 108-inch wheelbase. The narrow tread, and hence the possibility of a large ratio, has made the cyclecar the easy riding vehicle it is, yet many predicted hard riding. The lessons learned in the development of cyclecars has influenced the light-car designers in this respect and while there are more standard tread cars than under-standard, the ratio of wheelbase to tread has been made as large as possible, consistent with appearance and low weight.

Wheels. Wire wheels are used on the majority of light cars and in the selection of the proper type a number of difficulties have come up. At the beginning, it was thought that on account of the low weight of the car, wheels of less than ordinary strength could be used; but it was found that a number of conditions had been overlooked. It was found that wire wheels for light cars must be as strong as those of heavier vehicles, if not stronger, in proportion to the weight.

The reason that much thought was given to the subject was that the first wheels adopted gave such poor results. The majority of light cars are low hung, that is, the center of gravity is low. As the cars are small and light, their acceleration, turning, etc., are more rapid than in the heavy car. Hence wheels with ability to stand side strain to a great extent must be used. The outer wheels always are subjected to greater strains in turning. The light car, being hung low, imposes more side strain on the wheels than a high-hung car because, in the latter, the weight in taking a turn is more in the nature of down thrust. In the low-hung car most of the force is exhibited as side thrust and hence the wheels must be made to withstand greater stresses.

Light cars are equipped with one of two types of wheels, the double-laced or the triple-laced, Fig. 18. The triple-laced wheel is more able to withstand side thrust and direct load than the double-laced and, furthermore, is able to take the side strain in both directions to a greater extent.

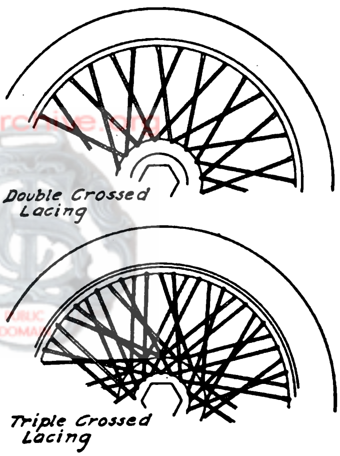


Fig. 18. Diagrams Showing Double-Crossed and Triple-Crossed Lacing for Wire Wheels

Brakes. While the first light cars used only one set of brakes, this having been found adequate in cyclecars, later experimentation showed that it would require two sets to do the work well. So manufacturers began installing rear-wheel brakes, acting both from a foot pedal and hand lever. Few used propeller-shaft brakes and those who did abandoned them, so that the present field is composed mostly of cars using two rear-wheel sets. One good example of departure from the conventional is in the Scripps-Booth. This car has one set of brakes operated by the clutch pedal and the other set from a separate pedal, the former being used as a service set and the latter for emergency. In the Scripps-Booth also, instead of employing metal rods for operating the brake bands, cables are used, not so much to reduce weight as to prevent rattling. The arrangement is shown in the detailed description of the Scripps-Booth, together with the method of adjustment which consists of a notched handwheel near the brake bands.

Bodies and Seating Arrangement. *Use of Streamline Shape.* Speed is just as necessary in the light car as in the heavier types and is possible with an expenditure of less power. This is due mostly to the reduction of wind resistance out of all proportion to the power of the motor. In the light car, speeds as high as those of the heavy cars are attainable, the strongest factor in bringing this about being the streamlining of the bodies. The streamline effect has been carried to the rear of the car as well as to the front,

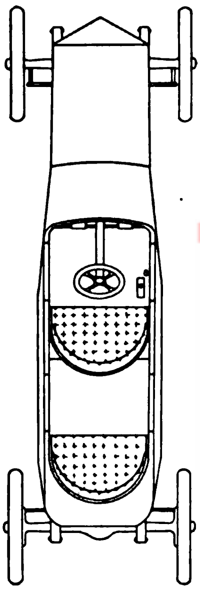


Fig. 19. Tandem Seating Arrangement for Light-Car Bodies

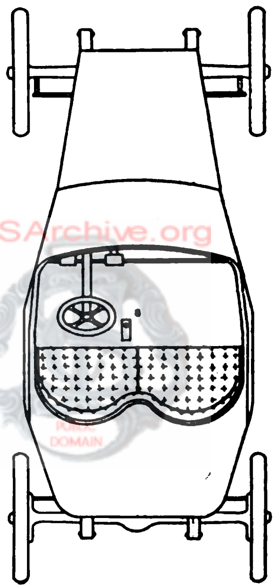


Fig. 20. Side-By-Side Seating Arrangement for Light-Car Bodies

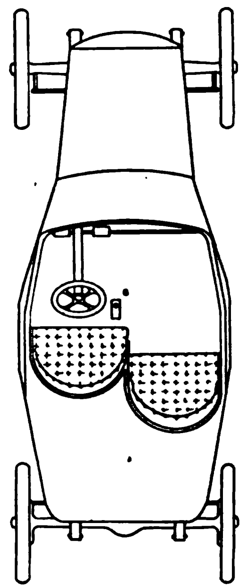


Fig. 21. Staggered Seating Arrangement for Light-Car Bodies

for, as is well known, the tendency to produce a vacuum at the rear does more to retard the speed of the vehicle than the resistance at the front. In the descriptions of the various light cars the streamline bodies are shown.

Tandem, Side-By-Side, and Staggered Seats. In cyclecars and early light cars, most of the designs used tandem seating, as shown in Fig. 19. This method of seating was used with two things in view: first, getting a better streamline body and thus allowing high speeds; and second, obtaining better weight distribution. It also was found necessary in many cases to use this construction because of the narrow tread. Many of the cyclecar designers insisted that side-by-side seating, Fig. 20, would lead and, therefore, did not adopt the tandem. While there were differences of opinion, one designer came along and used staggered seating, Fig. 21, which apparently overcomes the objections to both side-by-side and tandem.

In the tandem seater, it is urged, the passenger cannot converse with the driver without leaning over and thus make riding uncomfortable; and also, that riding without talking makes a trip monotonous. The leg room in a tandem seater is, in most instances, insufficient and it is stated that long-legged men have difficulty in sitting comfortably. In the side-by-side seater, while the passengers can converse and have plenty of room, the wind resistance is increased by using a wider body. This type also calls for a shorter wheelbase and the riding qualities are not as good as in the tandem.

The staggered arrangement is thought to be the happy mean, for the passenger is neither behind the driver nor directly beside him but just slightly behind. This method of seating, it is urged, allows of a slightly narrower body.

REPRESENTATIVE AMERICAN LIGHT CARS

Saxon. One of the first cars answering the description of the light car to make its appearance in America is the Saxon, with a four-cylinder, L-head block engine and selling for $395. The wheelbase is 96 inches and the tread standard, giving it a wheelbase-tread ratio of 1.41 to 1; and with this ratio and the suspension, the riding qualities are exceptionally good. This is due also to the proper proportioning of the weight above and below the axle, the theory of minimum unsprung weight being carried out to a great extent.

Motor. The motor has a bore and stroke of $2\frac{5}{8}$ by 4 inches, giving it a displacement of 86.6 cubic inches. It is of Continental make and the cylinders and upper portion of the crankcase are cast as a unit, a practice which is fast becoming standard even in larger motor construction. The siphonic system of cooling is employed as in practically all engines of its size. In the matter of carburetion, a very short mixing chamber leads from the carbureter to an intake manifold, cast integral with the cylinders, again showing the simplicity and unification necessary for the low-priced light-car construction. The engine is lubricated by the vacuum feed, or displacement method, as it is often called.

Lubrication. A small tank has leading from it a spout which extends into the crankcase. Oil from the tank will run into the case until the oil touches the end of the spout. As soon as the level drops, air is permitted to make its way into the tank, displacing some oil which is forced into the tank. In this way the oil level is kept constant and as high as the end of the spout.

Ignition. Simplicity again is evident in the ignition system which employs batteries, a coil, and a distributor of Atwater-Kent make. In this, the battery current is stepped up in the coil from

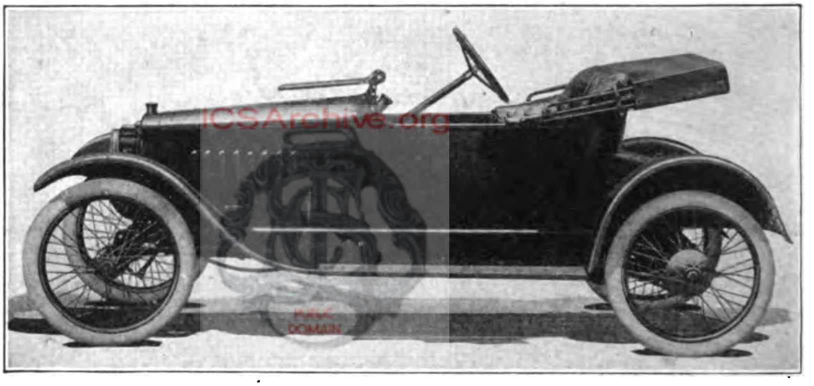


Fig. 22. Saxon Light Car with Full Running Boards and Head Lights in Front
Courtesy of Saxon Motor Company, Detroit, Michigan

which it is sent to a mechanically-driven distributor arm which, in turn, sends it to the spark plugs.

Transmission. Back of the engine is a five-plate disk clutch attached to a shaft by means of a universal joint at its forward end, the shaft operating in a torque tube. The gearset, a two-speed selective affair, is incorporated with the rear axle unit, the axle itself being of semi-floating construction, operating on Hyatt roller bearings.

Springs. In so far as springing is concerned, the Saxon shows adherence to substantial design by employing quarter-elliptic springs both front and rear, the length being 23 inches. For the weight carried, these springs have the advantage of low cost, easy riding, and low weight.

Body. The body is a two-passenger streamline fitted with gracefully curved fenders, left drive, and center control. The wire wheels, as shown in the Saxon illustration in Fig. 22, add much to the car's neat appearance.

Saxon "Six". The lowest-price six-cylinder car in America has been brought out by the Saxon Motor Car Company. This car sells for $785 and it is featured by a six-cylinder engine having block-cast cylinders, 2⅞ by 4½ inches, developing about 35 horsepower. The cylinder shape is L-head. Atwater-Kent ignition, thermo-siphon cooling, and gravity fuel feed are used.

The clutch is a multiple-disk driving a three-speed selective gearset located on the rear axle, a design which is in use on the Saxon four. The rear-axle construction is three-quarters floating in which the shafts take no weight, but are used only to turn the rear wheels and take torsional strains.

The wheelbase of the six-cylinder Saxon is 112 inches and the tires 32 by 3½ inches. In the equipment of this car is found a Gray and Davis cranking and lighting system which is included at the price mentioned.

Grant. *Six-Cylinder*. The first six-cylinder light car to make its appearance is the five-passenger Grant. The difference between this vehicle and the four-cylinder types lies principally in the addition of two more cylinders, as the running gear—axles, wheels, gearset, etc.—is of conventional design. The motor is a block casting with cylinders 2⅞-inch bore by 4-inch stroke, with overhead valves, and incorporated with it a cone clutch and three-speed gearbox. Ignition is by the Atwater-Kent booster system. The price of this six-cylinder light car is $795, which includes electric lighting and starting equipment. The wheelbase is 106 inches and the tread 56 inches.

Four-Cylinder. Aside from the six-cylinder model, a Grant four-cylinder car is on the market and in design is very similar to the Saxon, previously described. It is illustrated in Fig. 23. This car has a wheelbase of 90 inches and tread of 56, and sells for $425.

The motor has 2¾-inch by 4-inch cylinders cast in block, with intake and exhaust manifolds integral. Ignition is by a Bosch high-tension magneto; cooling is by the siphonic system; and oiling is by the vacuum system. The transmission units are a cone clutch and two-speed selective gearset mounted on the rear axle, which is of three-quarter floating construction.

Scripps-Booth. Perhaps the first light car to make luxurious fittings and easy riding the most essential points is the Scripps-Booth, which is made in three types, a roadster of three-passenger capacity, coupé, and cabriolet, the first-named selling for $775. While the price at first may appear high for a light car, the intentions of the designer were in the direction of supplying a vehicle to be sold to owners of high-priced cars who desire the maximum of

Fig. 23. Front View of Grant Roadster
Courtesy of Grant Motor Company, Findlay, Ohio

comfort and the best of everything in the matter of construction and design.

Motor. The Scripps-Booth, Fig. 24, uses a four-cylinder Sterling motor, which is of the valve-in-the-head design, with cylinder dimensions $2\frac{7}{8}$ by 4 inches. The ignition is by the Atwater-Kent system. Scripps-Booth cars are made with one wheelbase 110 inches, and three treads 40, 56, and 60 inches, respectively, giving quite a range of wheelbase-tread ratios.

Transmission. The drive from the engine is by a cone clutch and three-speed gearset, which are parts of the power plant, and thence by a hollow propeller shaft to a floating rear axle. A feature of the propeller shaft couplings is that they use ball bearings so that power losses due to shaft misalignment are eliminated to a great extent.

Miscellaneous Features. In the braking system of the Scripps-Booth, a novel arrangement has been devised. Cables are used instead of the conventional levers, and the adjustment means is by

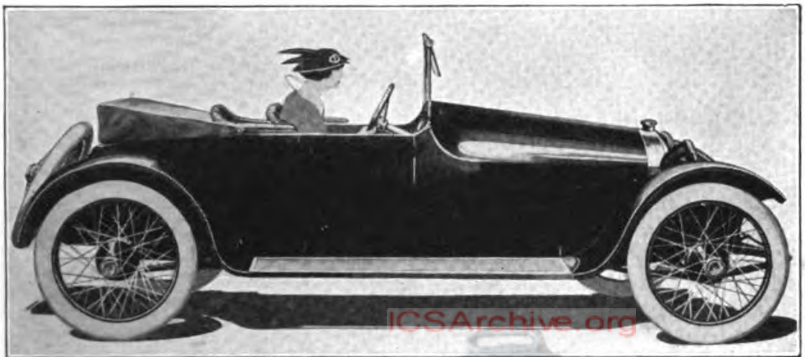


Fig. 24. Scripps-Booth Light Car
Courtesy of Scripps-Booth Company, Detroit, Michigan

a notched wheel as shown in Fig. 25. The spring suspension is by semi-elliptics in front and cantilevers in the rear. Houk wire wheels, fitted with 30- by 3½-inch tires are used.

The body is a well-designed streamline type and one of the notable features is the use of electric door locks, which operate on the principle of the house-door lock. Pressure on a button sends current through a solenoid, the core of which forms the latch, the latter being drawn back when the coil is energized.

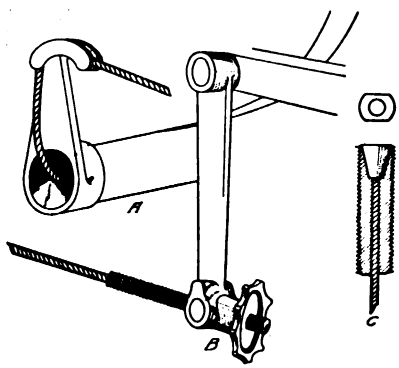


Fig. 25. Details of Scripps-Booth Brake Connections and Adjustment

Metz. The Metz car is featured with a friction-drive transmission in its simplest form. The engine is a four-cylinder water-cooled, which drives a single disk against which presses another disk mounted on a jackshaft, the ends of which are fitted with chains which drive the rear wheels. The differential is incorporated in the jackshaft. A special feature of the drive is that the chains are inclosed in a metal casing for protection against dirt and to obtain more quiet running. The Metz sells for $495 and has a 96-inch wheelbase and standard tread.

Partin-Palmer. Typical American practice is to be seen in the two-passenger, $495 Partin-Palmer which uses an L-head four-cylinder 2¾-inch by 4-inch motor, fitted with Atwater-Kent ignition. Nothing radical in design is seen in the engine. It drives through a cone clutch fitted with spring inserts to a three-speed gearbox, which is part of the rear axle assembly. The Partin-Palmer, which

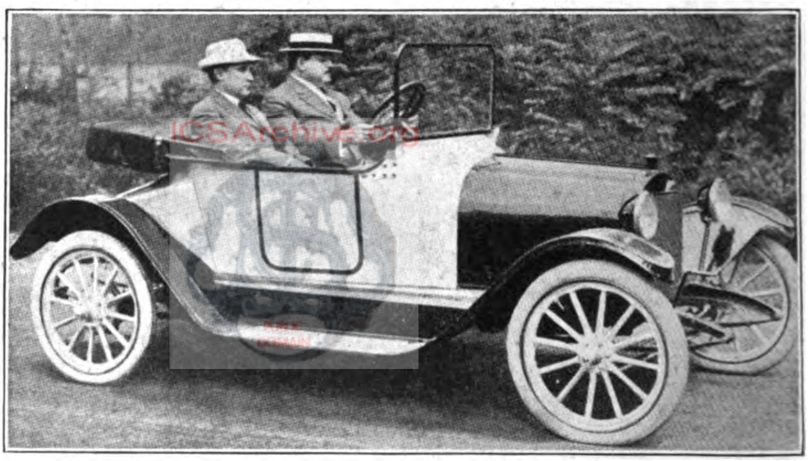


Fig. 26. Partin-Palmer Light Car
Courtesy of Partin Manufacturing Company, Chicago

has standard tread, is regularly fitted with a Gray and Davis lighting generator and a well-designed streamline body, as shown in Fig. 26.

Briscoe. European practice in a light car is to be seen in the Briscoe, a streamline car with unusual body features, as shown in Fig. 27, selling for $750. The engine is unusually large for a car of its class, the bore being 3⅛ inches and the stroke 5⅛ inches. This rather long stroke is evidence of a study of foreign design. Abroad, the engines have even a greater stroke-bore ratio than the Briscoe. The magneto is placed over the clutch housing and is driven by silent chain from the crankshaft. The camshaft also is driven from the rear.

In unit with the engine is an inverted cone clutch and a three-speed selective gearbox.

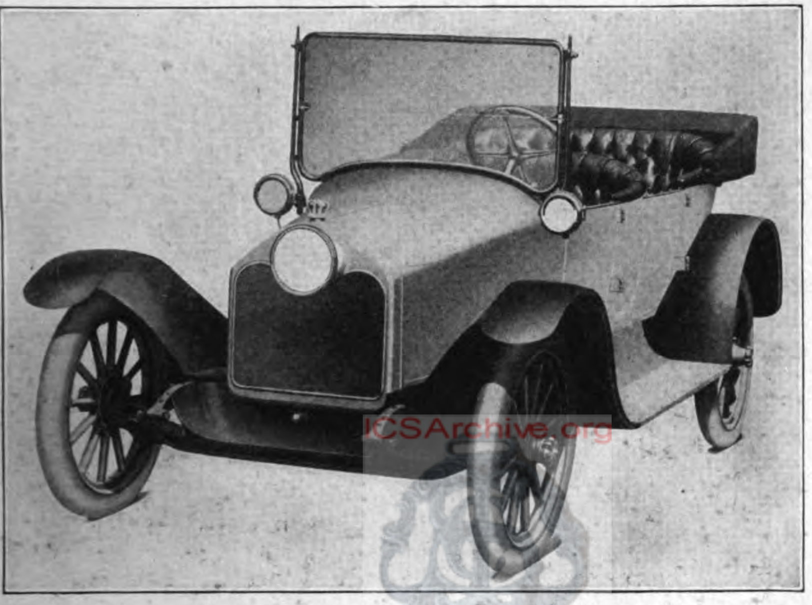


Fig. 27. Briscoe Light Car, Touring Body
Courtesy of Briscoe Motor Company, Jackson, Michigan

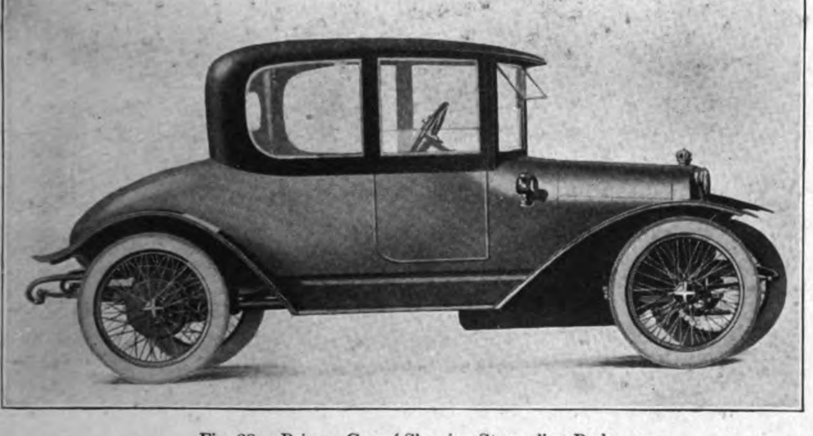


Fig. 28. Briscoe Coupé Showing Streamline Body
Courtesy of Briscoe Motor Company, Jackson, Michigan

The Briscoe also is marketed in coupé form, Fig. 28, which also shows the clever designing of the body of this light car.

Fig. 29. Vertical Section of Briscoe Chassis
Courtesy of Briscoe Motor Company, Jackson, Michigan

The chassis view of the Briscoe, Fig. 29, shows how the drive has been designed to be almost horizontal. The view also shows the odd magneto location. This car has a wheelbase of 107 inches and the body mounted is of unusual streamline design, as shown in the illustrations, a characteristic feature being the single headlight placed in the center of the radiator shell.

Imp II. A car which originally appeared as a cyclecar, but by redesigning has entered the light-car field, is the Imp, a friction-driven two-passenger car, selling for $395. A four-cylinder motor, 2$\frac{3}{4}$ by 4 inches, drives the friction set, which propels a live rear axle by chain. The front axle is tubular, the rear springs cantilever type.

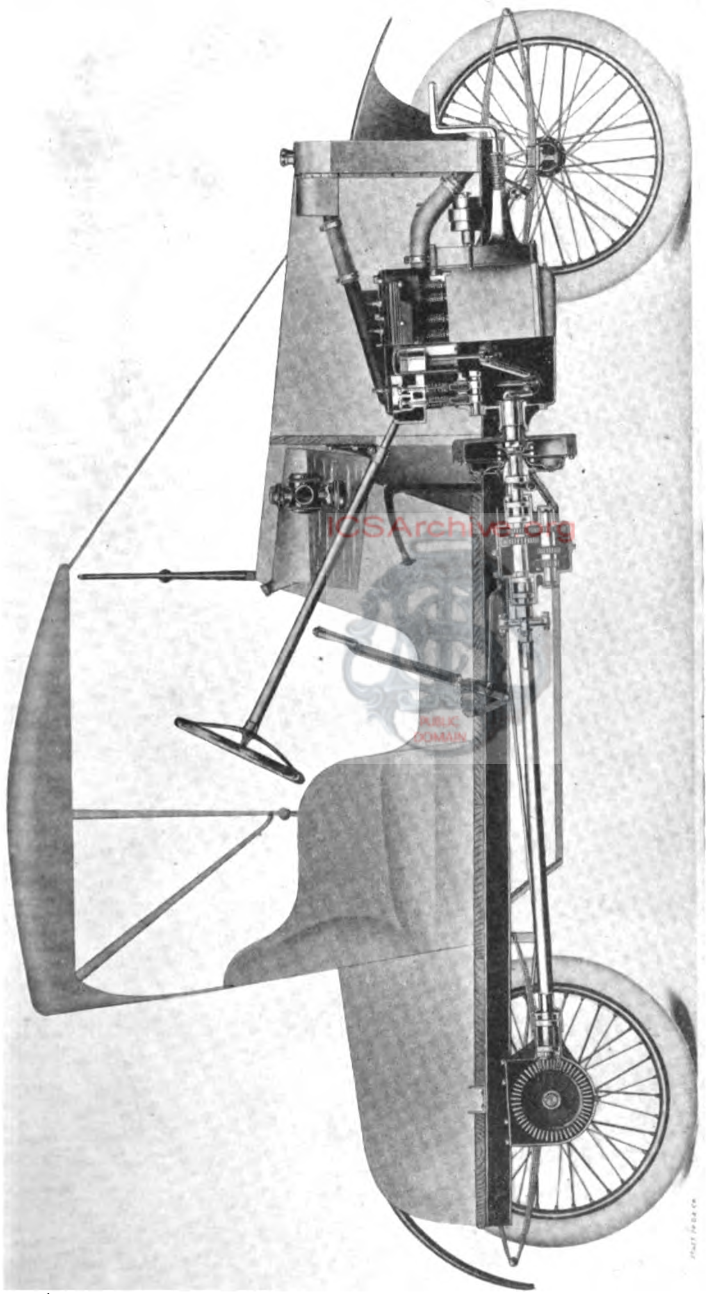


Fig. 30. Vertical Section of the Argo Light Car
Courtesy of Argo Motor Company, Jackson, Michigan

Argo. The Argo, an American-made car showing foreign characteristics, is from the designs of Benjamin Briscoe, who developed the vehicle across the water. This is his latest achievement and it is one of the lowest-priced light cars on the market, selling for $295 in two-passenger form. In the matter of design, there is nothing unusual. The motor has four cylinders, $2\frac{5}{16}$ by 4 inches, and it drives an inverted cone clutch and two-speed gearset, which are separate units, as shown in Fig. 30. The extreme lightness of this vehicle is due primarily to its simplicity, there being no parts with unnecessary dimensions or weight. The design is for quantity production.

Cornelian. The two-passenger Cornelian has features which differentiate it from all other American types, this vehicle employing

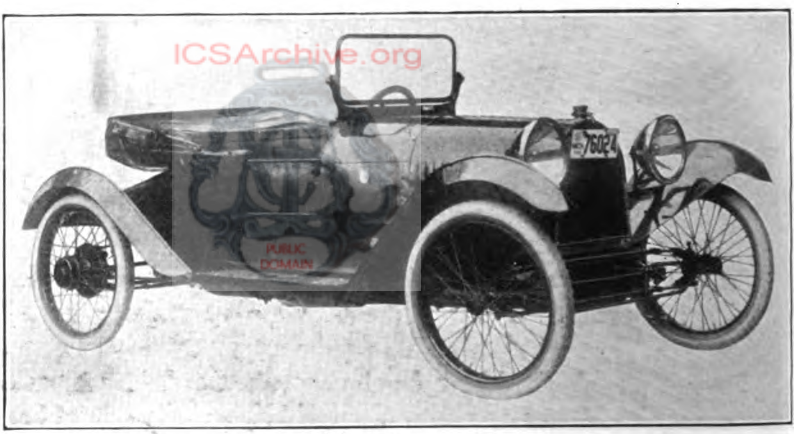


Fig. 31. Cornelian Light Car
Courtesy of Blood Brothers Machine Company, Kalamazoo, Michigan

De Dion drive spring axles and a steel body made a unit with the frame.

At the rear of the frame is the gearbox and differential unit. At the ends of the axle shafts and on each side of the gearset are universal joints, thus making four joints in the drive. This construction makes it possible to take care of all relative motion between the body unit and the wheels. This drive is a modification of the drive used for a number of years by the French maker, De Dion. That power losses due to the four joints will not be obtained is evident when the maximum car speed is mentioned, which is close to 70 miles per hour.

The springing of the Cornelian also is unusual. In front, semi-elliptic transverse springs are used, one above the other, and the method of mounting is shown in Fig. 31. In the rear, what is called a "platform spring axle" is used, which is made up of three semi-elliptic springs, two being on the same plane and the third 9 inches above. The body load is taken at the center and is carried out to short axle tubes at their ends. In this way the ordinary axle housing is done away with and the unsprung wheel and axle weight cut down considerably.

The Cornelian uses a four-cylinder 2¾-inch by 4-inch motor of Sterling make and a disk clutch. The wheelbase is 96 inches and the tread 56 inches.

Woods Mobilette. In the Woods mobilette is an example of tandem seating used almost entirely in cyclecar practice, but rather

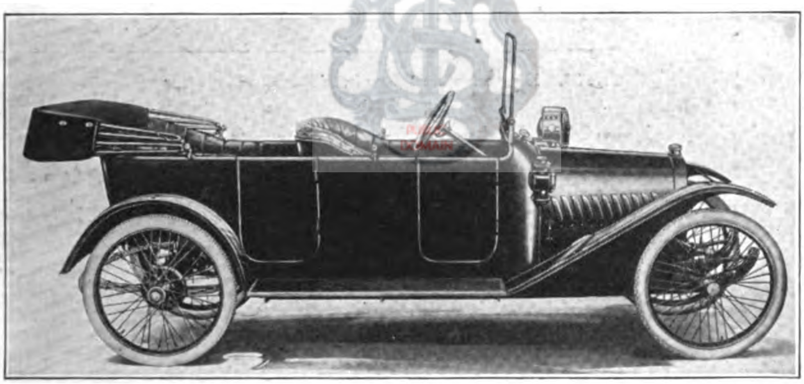


Fig. 32. Woods Mobilette
Courtesy of International Cycle Car and Accessories Company, Chicago, Illinois

scarce in the light-car field. While the photograph in Fig. 32 may make the car appear like a five-passenger, it is in reality a two-passenger and sells for $380. The tread is 36 inches and the wheelbase 102 inches, giving a wheelbase tread ratio of 2.86 which, theoretically is conducive to easy riding. The chassis has a four-cylinder motor, cone clutch, and two-speed gearset mounted on the rear axle. A feature of the Woods is that a commercial or limousine body may be mounted on the same chassis.

Princess. One of the novel features in construction of the Princess light car is that the radiator is placed under the hood. This is possible because a sloping, European-type hood is used as shown in Fig. 33. The illustration shows also the arrangement of the various parts such as fuel tank, luggage space, etc., and brings out the rear spring suspension by semi-cantilevers. The Princess is of 44-inch tread and 92-inch wheelbase and is equipped with a four-

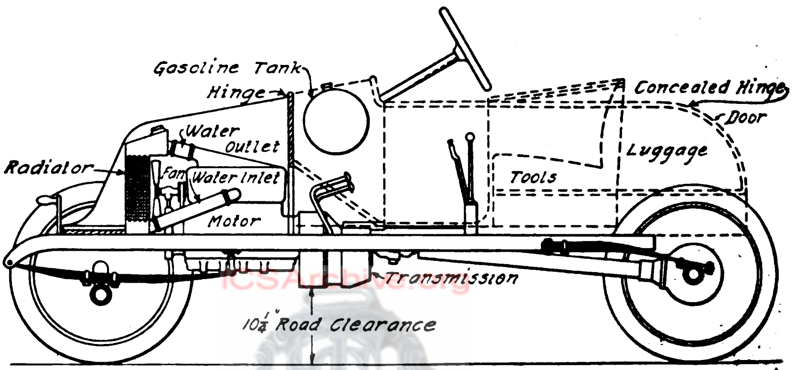


Fig. 33. Diagrammatic View of the Princess Light Car

cylinder engine with cylinders 2$\frac{3}{4}$ by 4 inches. The engine is thermo-siphon cooled and drives to the rear wheels through cone clutch and three-speed gearbox to a semi-floating rear axle. The price is $475.

Herreshoff. Another narrow-tread vehicle is the Herreshoff, designed by the well-known builder of racing yachts, Charles Frederick Herreshoff. This latest achievement of Mr. Herreshoff has a 44-inch tread and 94-inch wheelbase and gives a very pleasing appearance when fitted with wire wheels. An Entz cranking and lighting system is fitted to this vehicle, which is sold at $500. The motor is a four-cylinder type, with cylinders 2$\frac{3}{8}$ by 3$\frac{1}{4}$ inches. The running gear details show no special features.

Alter. This is a comparatively new light car, selling for $800 and showing the general lines employed in big-car practice. The motor is a four-cylinder type, with cylinders, block-cast and of L-head construction 3$\frac{3}{8}$ by 5 inches. The motor is part of a unit power plant, with a cone clutch and three-speed gearset. The tread is standard.

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starting and lighting equipment. It is a five-passenger car with a 110-inch wheel base, standard tread, and drives through a disk

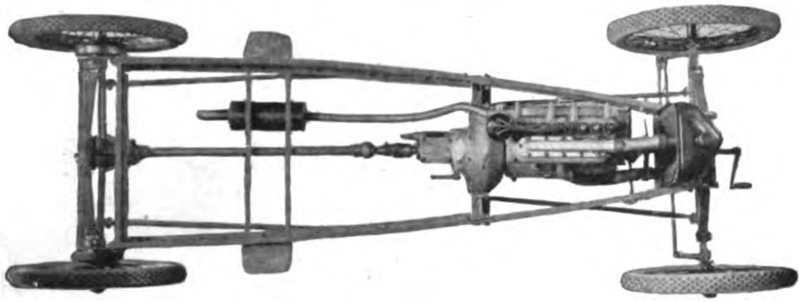


Fig. 35. Chassis of the Dudley Light Car
Courtesy of The Dudley Tool Company, Menominee, Michigan

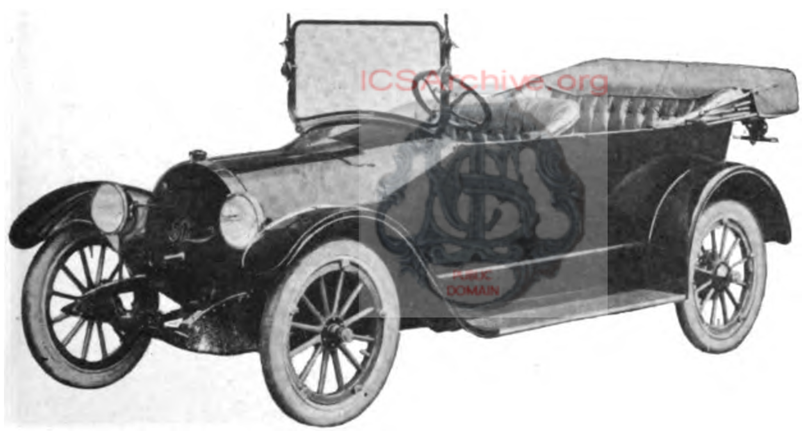
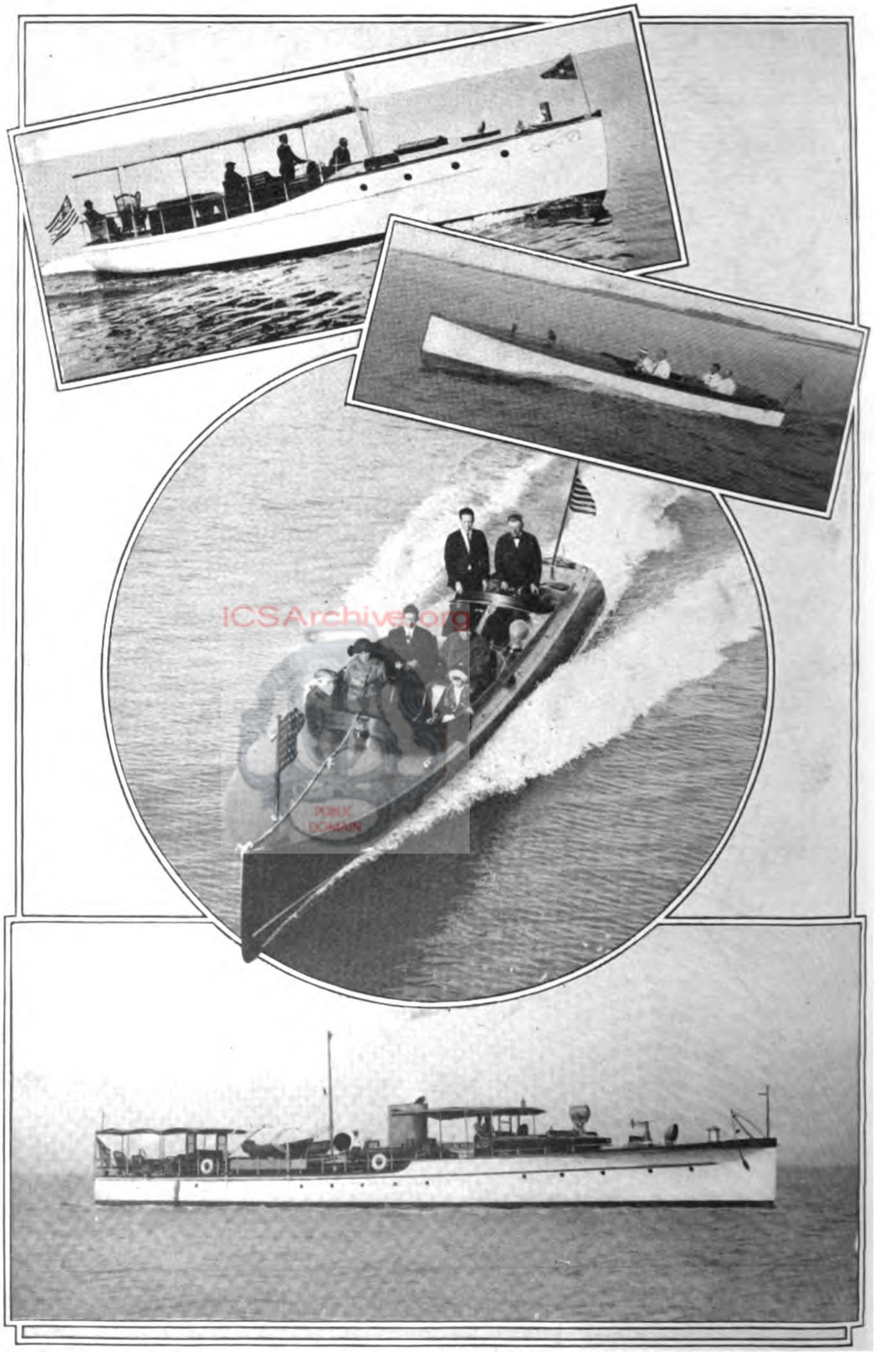


Fig. 36. Pullman Light Car
Courtesy of Pullman Motor Company, York, Pennsylvania

clutch and three-speed gearbox to a three-quarter-floating rear axle. The rear suspension is by cantilevers and the motor is of the four-cylinder block-cast type, size $3\frac{3}{4}$ by $4\frac{1}{2}$ inches.



GROUP OF MOTOR-DRIVEN PLEASURE CRAFT

Top Left—45-Foot Elco Cruiser; Top Right—30-Foot Matthews Launch "Wanderlust"; Center—40-Foot Matthews Launch "Hermes"; Lower—100-Foot Matthews Cruiser "Marold"

MOTOR BOATS

[C. H. Hug[illegible]

INTRODUCTION

Types Discussed. Under the heading "Motor Boats" are broadly included all vessels driven by explosive engines; but in this article, although mention is made of the Diesel engine, the bulk of the matter is devoted to that type of craft popularly known as motor or power boats, including those used both for pleasure and commercial purposes.

For pleasure, there are certain standard types, such as open launches, runabouts, and cruisers. In this connection mention should also be made of hydroplanes, which are practically only racing machines.

For commercial purposes, tugs, lighters, and passenger boats driven by motors (explosive engines) are in extensive use; in fact, motors have proved so satisfactory for marine propulsion for small boats that they have been installed in some of the largest cargo vessels afloat and from the results obtained, it would seem that in the near future they will, for certain routes, replace steam engines and turbines.

HULL CONSTRUCTION

Definitions. *Displacement.* Displacement is the weight of the water displaced by a boat; or, in other words, it is the weight of the hull, including the engine and all equipment on board. Displacement is given in pounds or tons. If the latter, a ton of 2240 pounds is generally used although on the Great Lakes a ton is taken as 2000 pounds. Calculations for the displacement are made to the extreme dimensions, that is, to the outside of the planking, but in large steel vessels it is calculated to the outside of the frames, or the inside of the shell plating. A cubic foot of fresh water weighs 62.5 pounds and of salt water 64 pounds, consequently it will take 36 cubic feet of fresh water or 35 cubic feet of salt water to weigh one ton (2240 pounds).

Center of Buoyancy. The center of buoyancy is the center of gravity of the under-water volume of a boat.

Transverse Metacenter. Assume that a boat is floating in still water, Fig. 1. Under normal conditions WL will be the water line, B the center of buoyancy, and G the common center of gravity of the hull, machinery, and all the weights on board.

If the boat is inclined at a small angle, then $W'L'$ is the new water line, and the new volume of displacement $W'AL'$ has its center of buoyancy at B'. The upward force of buoyancy acts through B', while the weight of the boat acts vertically downward through the center of gravity G.

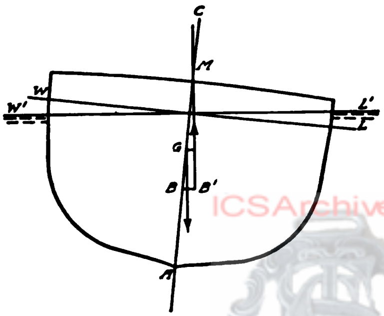


Fig. 1. Diagram Showing Metacenter

A vertical line through B' cuts the center line AC at M, and this point M is called the metacenter, and the distance GM the transverse metacentric height.

(a) If G is below M the boat is in stable equilibrium

(b) If G is above M the boat is in unstable equilibrium

(c) If G coincides with M the boat is in neutral, or indifferent equilibrium

While a good metacentric height is desirable for stability, it can be made such a height as to render a boat very uncomfortable in a seaway. For example, a boat inclined by the force of a wave may return to the upright position again with a sudden and unpleasant jerk. This can be overcome by spreading, or winging out, the weights and raising them, as by moving an ice box or other weight from the hold to the deck, and by shifting the lifeboats to the sides of the boat if they are stowed in the center.

Trim. Trim is the difference between the drafts forward and aft. Suppose a boat draws 4 feet at the bow and 4 feet 6 inches at the stern, then she is said to trim 6 inches by the stern.

Block Coefficient. Block coefficient is the ratio of the volume of the displacement in cubic feet to the volume of a block having the same length, breadth, and draft. In pleasure boats this varies within wide limits, as from .4 to .6, while for tugs and lighters it is about .7 to .8.

Tons per Inch of Immersion. Tons per inch of immersion is found by dividing the area of the water plane at which a boat is

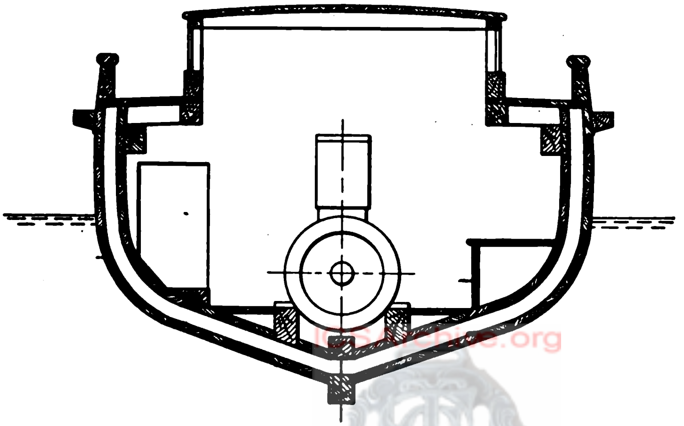


Fig. 2. Midship Section of Fifty-Foot Tugboat Similar to One Shown in Fig. 3

floating by 35 (weight of a ton of salt water, and if in fresh water by 36) times 12 inches. From the tons per inch of immersion can

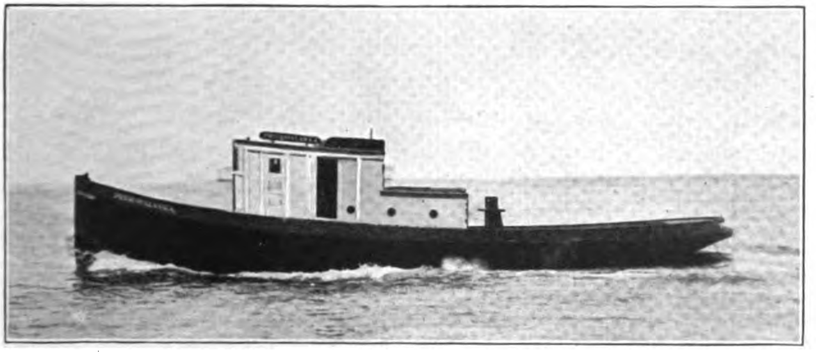


Fig. 3. Fifty-Two Foot Tugboat, Driven by Two 50-Horsepower Atlas Engines
Courtesy of Atlas Gas Engine Company, Oakland, California

be found the draft of a boat after known weights have been placed on board.

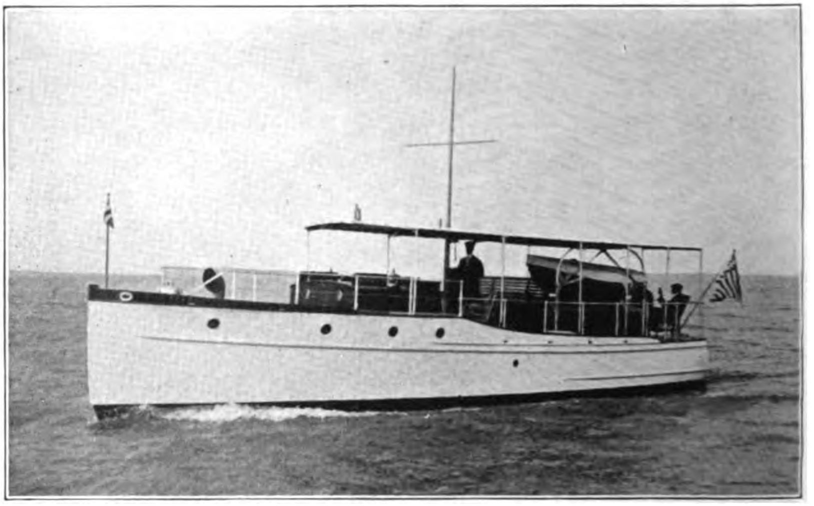


Fig. 4. Forty-Five-Foot Cruiser
Courtesy of Matthews Boat Company, Port Clinton, Ohio

For example: A cruiser 60 feet long, 15 feet beam, has a water-plane area of 720 square feet. She has a draft of 5 feet in salt water, and stores are added weighing 10 tons without changing her trim. What is her new draft?

$$\text{Tons per inch of immersion} = \frac{\text{area of water plane}}{35 \times 12} = \frac{720}{420} = 1.73$$

Fig. 5. Sixty-Six-Foot Cruiser
Courtesy of Matthews Boat Company, Port Clinton, Ohio

Hence, if 10 tons were added, this would mean the draft would be increased 10 times 1.73, or 17.3 inches and the new draft would be 6 feet 5.3 inches.

Types of Hulls and Construction. *Usual Form.* Motor boats have been given an endless variety of under-water forms because the

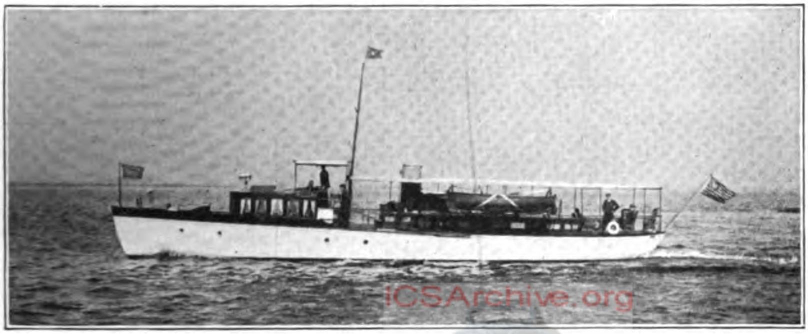


Fig. 6. Seventy-Five-Foot Motor Yacht
Courtesy of Elco Company, Bayonne, New Jersey

Fig. 7. Thirty-Foot Launch
Courtesy of Elco Company, Bayonne, New Jersey

design of the hull must be suited to the service the boat is to be engaged in. The form most generally accepted is to have the cross sections curved, as in Fig. 2, which is the midship section of a 50-foot tugboat similar to the one shown in Fig. 3.

The under-water form is of course radically different in different types; for instance a cruiser, Figs. 4 and 5, or a yacht, Fig. 6, would have fuller cross sections than a fast runabout, Fig. 7, while a lighter or a freight boat would have very full cross sections. The frames are bent by steam, and at the top are knees connecting the frames and beams. The outside planking is usually flush, although sometimes in small launches and surfboats it is lapped.

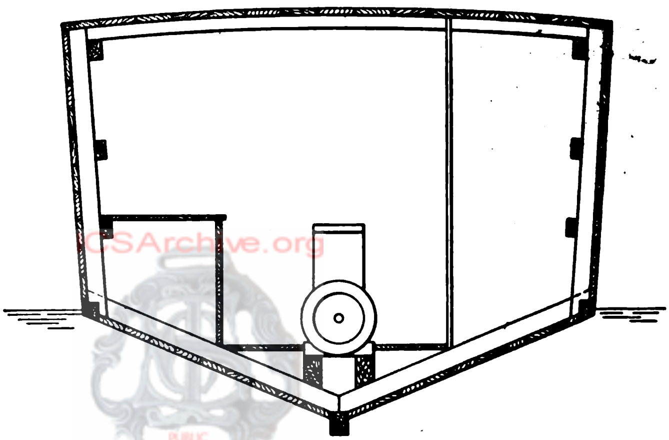


Fig. 8. Midship Section of Twenty-Eight-Foot V-Bottom Cruiser

V-Bottom Form. A form that has proved very satisfactory for motor boats is the V-bottom, Fig. 8, a cruiser of this design being illustrated in Fig. 9. In this type the under-water sections forward have a decided concavity gradually working straight at transom, while the above-water sections are flared forward and rounded aft. With this type there is no necessity for steam-bending any parts of the framing or planking. The angular bilge and general form of the bottom sections provide hulls which are free from the disagreeable rolling usual in round-bottom boats when running in cross seas. Furthermore, the hulls are easy to drive, and excellent speeds have been obtained even when equipped with low-powered motors.

Hydroplane Form. For racing, a special type of boat, called the "hydroplane", has been developed in the past few years, which, instead of cutting through the water, slides or skims over it. A cross-section of the bottom may show it to be flat, or a very flat V-form, Fig. 10, or it may have the V-form but with slightly concave lines.

Fig. 11 is an outboard profile of a hydroplane with a single step, although sometimes there are three or more. As the speed

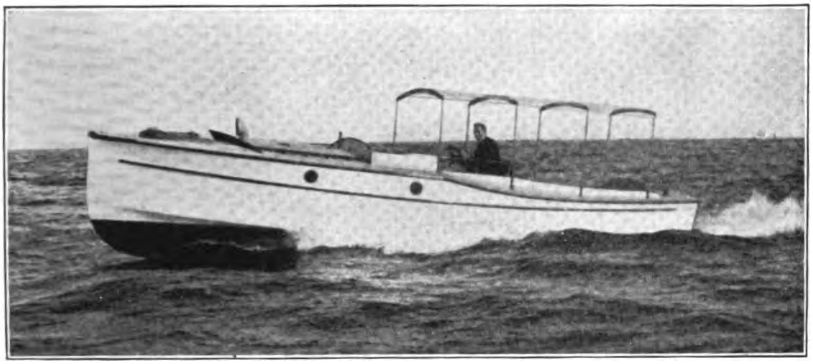


Fig. 9. V-Bottom Cruiser
Courtesy of W. H. Hand, Jr., New Bedford, Massachusetts

of the engine is increased, the hydroplane lifts or rises from the water as shown in Figs. 12 and 13. When it is lifting, the question of balance is a most important one, for the ordinary rules for calculating stability cannot be strictly followed. Instances are known of boats that from their plans appeared to be perfectly stable, yet when running at high speeds have capsized. This type has no commercial value, and is built solely for racing. Remarkable speeds have been obtained, in some cases as high as 53 miles an hour. In hydroplanes

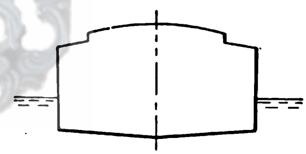


Fig. 10. Cross Section Through AA of Flat V-Bottom Hydroplane, Fig. 11

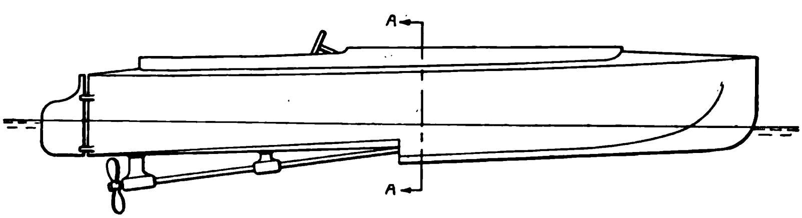


Fig. 11. Diagram of Hull of Typical Hydroplane Showing Single Step

and speed boats with round or V-bottoms, the frames are very light and, to give the requisite strength, the hull in many cases is planked with two thicknesses of thin material closely riveted together. Sometimes the hulls are stiffened with steel and bronze braces and, in place of a wood deck forward, have the beams covered with canvas.

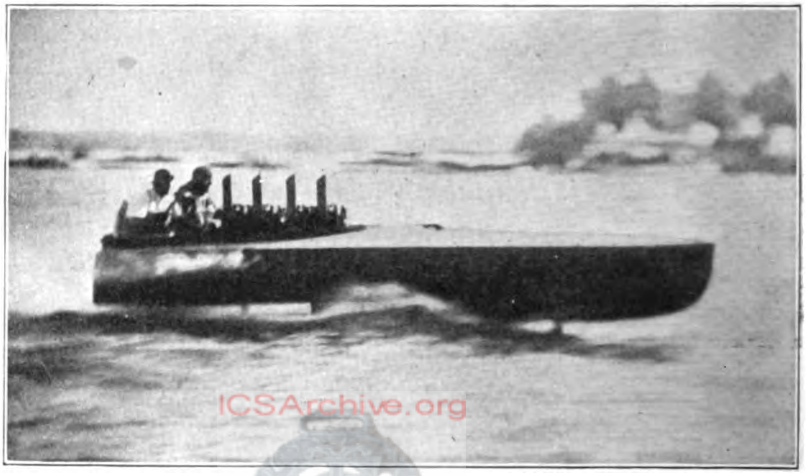


Fig. 12. Hydroplane "Baby Demon II"
Courtesy of C. C. Smith Boat and Engine Company, Algonac, Michigan

Fig. 12 is the hydroplane "Baby Demon II", built by the C. C. Smith Boat and Engine Company, and driven by an eight-cylinder

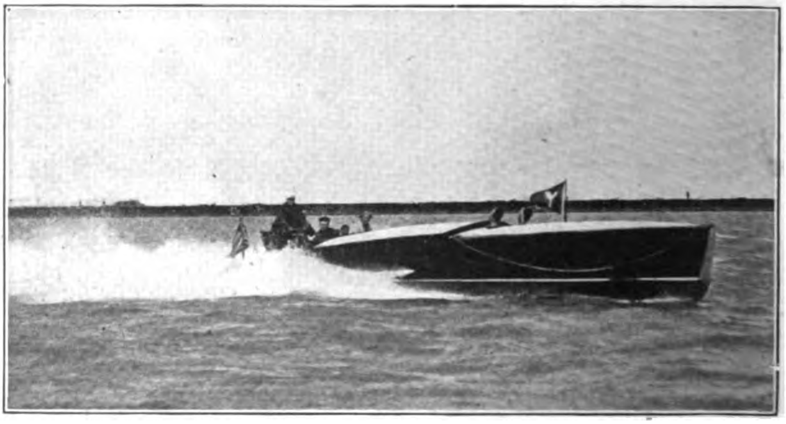


Fig. 13. Hydroplane "Disturber III" Driven by Two 250-Horsepower Van Blerck Motors
Courtesy of Van Blerck Motor Company, Monroe, Michigan

Sterling engine. She is one of the fastest boats ever built. Another is "Disturber III", Fig. 13, 39 feet 10 inches long, with a hull of two

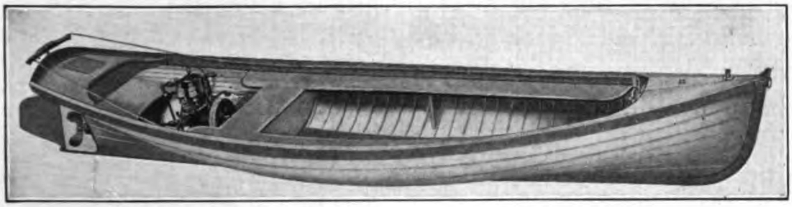


Fig. 14. Motor Boat with Metal Hull
Courtesy of Michigan Steel Boat Company, Detroit, Michigan

Fig. 15. Power Tank Delivery Launch "Sylvia". Length 70 Feet, Capacity 10,000 Gallons
Equipped with 50-Horsepower Standard Gasoline Engine
Courtesy of Standard Motor Construction Company, Jersey City, New Jersey

Fig. 16. Inspection Boat Equipped with Automatic Engines
Courtesy of Automatic Engine Company, Bridgeport, Connecticut

thicknesses of mahogany planking, and driven by two twelve-cylinder engines, 6¼-inch diameter by 7¾-inch stroke. She is without doubt the highest, or one of the highest, powered craft of her size ever constructed.

If a boat of very shallow draft is required, the propeller runs in a tunnel extending above the bottom of the boat. When the boat is under way the tunnel becomes filled with water, and the propeller, even if of greater diameter than the draft of the boat, is completely submerged in water.

Materials. *Wood Frame and Metal Hull.* All the motor boats of the types heretofore described have outside wood planking, but there are builders who turn out launches with metal hulls. Some of

Fig. 17. Motor Yacht "Aelgdytha", 110 Feet Long and Driven by Diesel Engines
Courtesy of Matthews Boat Company, Port Clinton, Ohio

these hulls have plates lapped together fore and aft, as in Fig. 14, while others are made in sections 30 inches or more long by the full beam, which are riveted together. Fig. 14 shows a 16-foot launch having wood frames, on the outside of which are heavy galvanized steel plates with lock seams spaced four inches apart. At the seams there are four thicknesses of metal, thereby making a strong hull and one that is absolutely water-tight.

Wood Frame and Hull. Commercial boats, such as the tank boat and inspector's launch shown, respectively, in Figs. 15 and 16, as well as the average pleasure craft, Fig. 17, have frame, keel, stem, sternpost, and beams of oak, although the latter are often of pine or spruce. The outside planking is of pine, cypress, or cedar with, in the case of pleasure boats, an upper or sheer strake of mahogany for appearance's

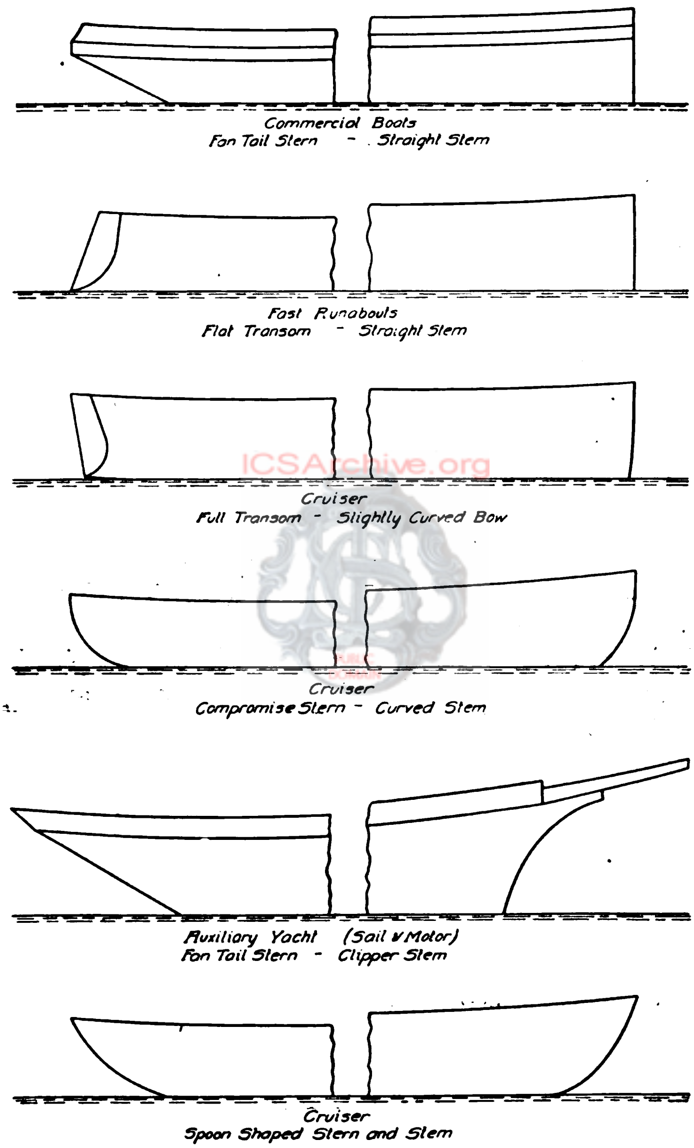


Fig. 18. Types of Bows and Sterns for Commercial and Pleasure Craft

sake. The planking is fastened to the frames by galvanized iron screws or nails, or preferably by copper rivets and burrs. For the decks, cedar or pine is used, although in some racing boats the beams are only covered with canvas. In high-speed boats the outside planking is often of mahogany, which can be given a beautiful finish. The planking is caulked; that is, cotton is driven into the seams between the planks by a caulking iron which is hit with a mallet. The cotton must be well forced in, making a water-tight surface.

After the outside planking has been caulked it is gone over lightly with a plane and then smoothed off, first with coarse and then with fine sandpaper. The hull is next cleaned with a stiff brush which removes any dirt or sawdust, and the hull is then ready to be painted or varnished. If the boat is to be used in dirty water, the bottom should be painted with an anti-fouling paint.

The colors of the hull and deckhouse are a matter of taste with the owner, as is also the interior finish. In many motor boats no pains have been spared in fitting up the staterooms and living quarters attractively.

Stems and Sterns. The appearance of a boat depends largely on the lines of her stem and stern and on the curve or sheer of the deck fore and aft. Care must be exercised in the stem and stern selected; for example, it would be absurd to give a slow traveling tugboat a clipper or overhung bow as used for a sailing boat. In Fig. 18 is shown various types of bows and sterns for commercial and pleasure craft.

MARINE MOTORS

Fuels. *Liquid Fuels.* Marine engines of the explosive type (commonly called motors) are run on a variety of fuels, such as gasoline, kerosene, distillate, and producer gas. Crude oil can be used satisfactorily only in Diesel or semi-Diesel engines.

In different parts of the United States certain fuels are more common than others. For example, along the Atlantic Coast either gasoline or kerosene is used, and more of the former than of the latter. On the Pacific Coast a fuel called distillate is popular and excellent results are secured with it, as is shown by the large number of pleasure and commercial boats running on it.

Kerosene is generally cheaper than gasoline although it is not so powerful. Engines using kerosene do not start so quickly as do those using gasoline, and they cannot be controlled so easily. With kerosene the engine has one speed at which it runs better than at any other, consequently kerosene is suitable only for boats running for long periods at a constant speed. Furthermore, kerosene is not so clean as gasoline and causes carbon deposits in the cylinder which must be cleaned out. So it is doubtful whether an engine using kerosene, a cheaper fuel than gasoline, has any advantages over gasoline, when the adaptability to changes of speed of the motor and the freedom from carbonization obtained with gasoline are considered.

Liquid Fuel Consumption. Motors operating on gasoline consume on an average about one pint per horsepower per hour. Kerosene engines require about six per cent more fuel than gasoline engines to get the same power. Diesel engines have been run on only .54 of a pint of crude oil per horsepower per hour.

Producer Gas. Engines running on producer gas have been installed in some small commercial craft, the builders of which have claimed low operating costs. But as gas producers take up considerable room, and as additional space must be provided for the storage of coal, liquid fuels, on the whole, are much more popular for marine use.

Cycles of Operation. The cycles of operation of marine engines for motor boats are the same as for all explosive engines and are described in the section on "Explosion Motors".

Two-cycle marine motors not running on the Diesel principle are seldom built larger than 10 or 12 h. p., as above that size they are invariably of the four-cycle type.

Diesel engines are built only in large sizes—from 50 up to several thousand h. p.—and have been installed in many freight boats, because of the small space they take up and the cheap grade of fuel they can use.

There is a modification of the Diesel often called the semi-Diesel which has been used in many commercial boats. Here the air is compressed as in a Diesel engine, but the compression is not carried to such a high point, and the explosive charge is ignited by a torch.

TYPES OF MOTORS

Classification. Motors may be divided into three broad classes, viz, *high* speed for hydroplanes, fast runabouts, and racing boats; *medium* speed for pleasure craft in general; and *slow* speed, heavy-duty for tugs, lighters, and passenger boats.

High-speed motors have several cylinders of a small bore and stroke, short connecting rods, with the crankshaft revolving at 1000 or more revolutions per minute, and with all the parts as light as possible. This type is chiefly for intermittent service, as for racing, and not for the day-in-and-day-out service required for medium and heavy-duty engines.

Heavy-duty motors, or motors for constant service, on the other hand have fewer cylinders but with a greater bore and longer stroke, longer connecting rods (thus taking off the cylinder walls the heavy side thrust which occurs with short rods), and the revolutions of the crankshaft do not exceed about 350 per minute. The parts, such as the crankshaft and connecting rods, are made more substantial, and the bearings are longer in the base plate. In this type the engine is expected to run for long periods without stopping and must be economical in the consumption of fuel.

Intermediate between the high-speed and the heavy-duty is the medium, a compromise of both.

High-Speed Motors. *Sterling.* A typical example of a high-speed motor built by the Sterling Engine Company of Buffalo, New York, is shown in Fig. 19. When running at 1500 revolutions this engine can develop 225 h. p., and weighs only 1460 pounds. It has eight cylinders, each $5\frac{1}{2}$-inch bore by $6\frac{3}{4}$-inch stroke, cast in pairs and bolted to a manganese bronze base. The inlet valves are of nickel steel, and the exhaust valves are of a special tungsten steel, the use of which does away with the old troubles of warping, pitting, and the necessity of regrinding. This engine has been installed in hydroplanes and fast runabouts. With two of these engines in the hydroplane "Ankle Deep", only 32 feet long, a speed of 52 miles an hour was secured. A single engine in the 40-foot runabout "Fad" easily made 27 miles an hour.

Van Blerck. Another high-speed motor is the one shown in Fig. 20, built by the Van Blerck Motor Company of Monroe, Michigan. It has six cylinders $5\frac{1}{2}$-inch diameter by 6-inch stroke, and,

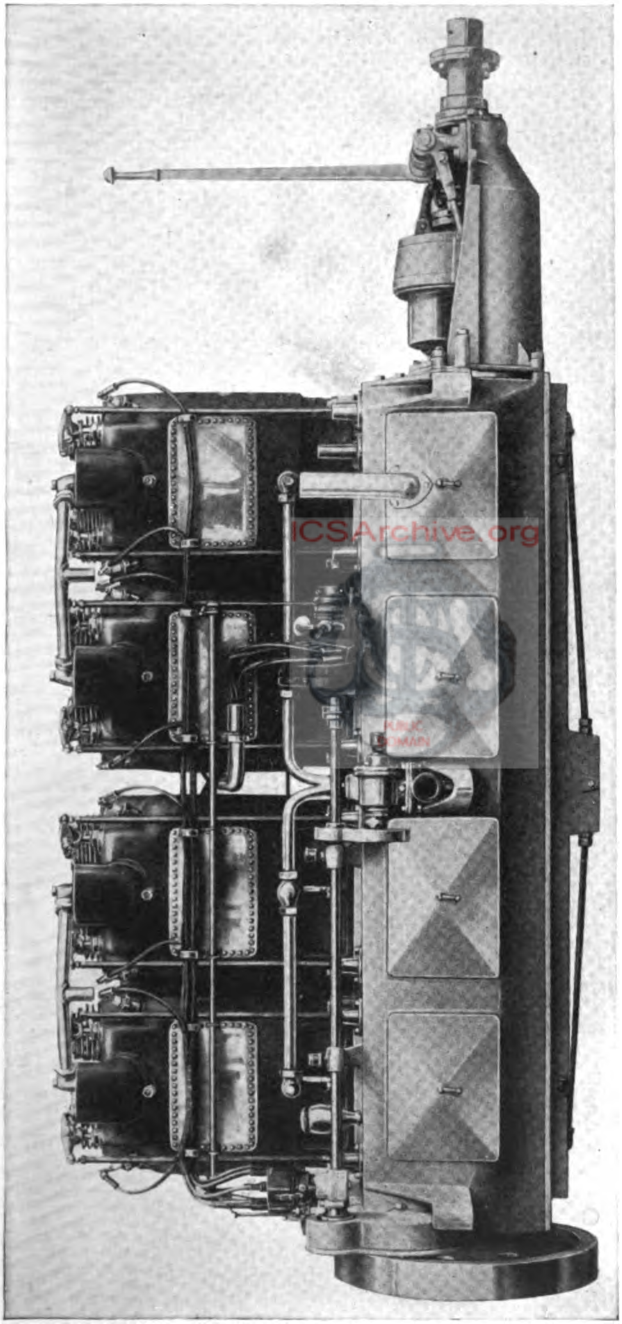


Fig. 19. High-Speed Sterling Engine of 225 Horsepower
Courtesy of Sterling Engine Company, Buffalo, New York

when running at 1200 revolutions per minute, develops 100 h. p. On referring to Fig. 20, it will be noted that the engine is electrically started, the motor being shown at the right connected to the crankshaft by a silent chain. The Van Blerck Motor Company also builds a twelve-cylinder type, which, when installed in hydroplanes such as "Disturber III", Fig. 13, and the "Kitty Hawk V", has driven them at exceptional speed, the latter boat, although only 26 feet long, making 53 miles an hour.

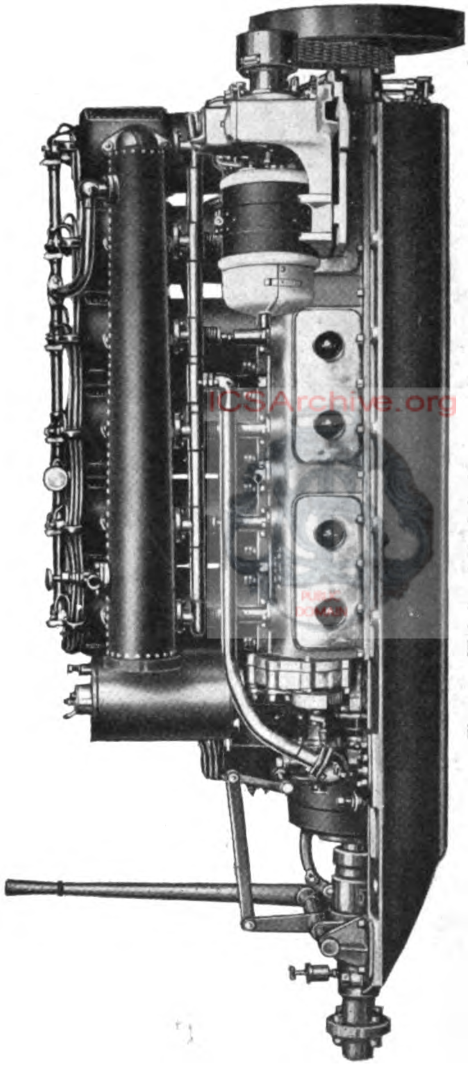


Fig. 20. High-Speed Six-Cylinder Marine Engine
Courtesy of Van Blerck Motor Company, Monroe, Michigan

Medium-Speed Motors. In a medium-speed motor the connecting rods are longer in proportion to the stroke than in a high-speed and the various parts are more heavily constructed. For example, instead of having a bronze or aluminum crankcase as in high-speed motors, they are of cast iron. The medium speed is particularly adapted to cruisers and other pleasure craft, where voyages of several days are made, the engine running continuously and the boat making say 10 or 12 miles an hour.

Loew-Victor. An engine of this class is illustrated in Fig. 21, which is of a four-cylinder 25 h. p., built by the Loew-Victor Engine Company of Chicago. This engine is suitable for cruisers up to 40

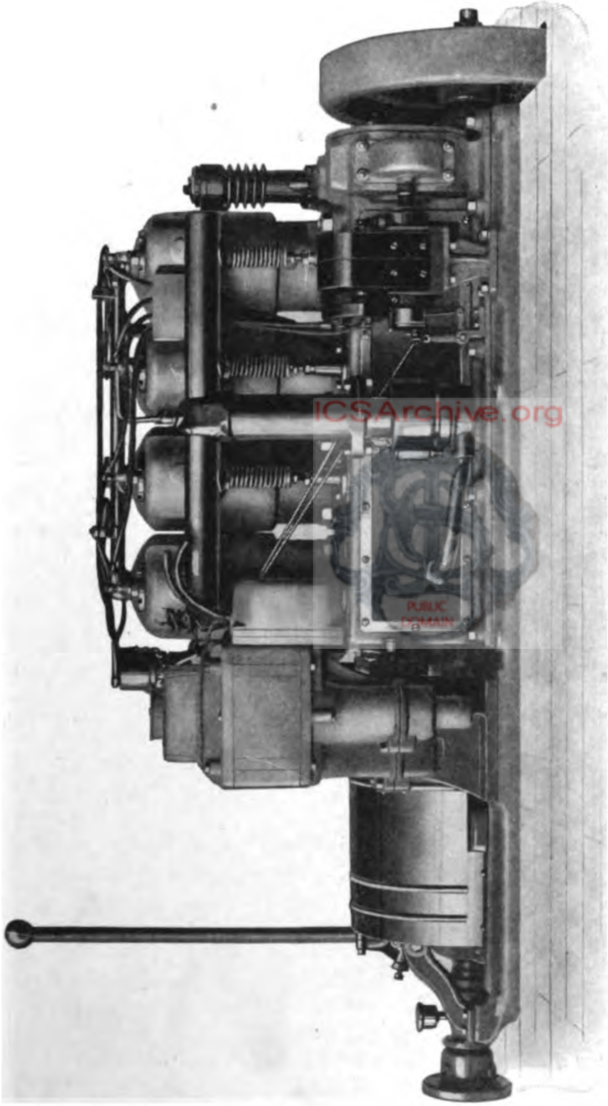


Fig. 21. Medium-Speed Marine Engine
Courtesy of Loew-Victor Engine Company, Chicago

feet in length. It is started by an electric motor shown at the left in the figure, while at the right is an air compressor bolted to the crankcase. Below the compressor and a little to the left is a Bosch high-tension magneto. The cylinders are $4\frac{3}{4}$-inch diameter by $5\frac{1}{2}$-

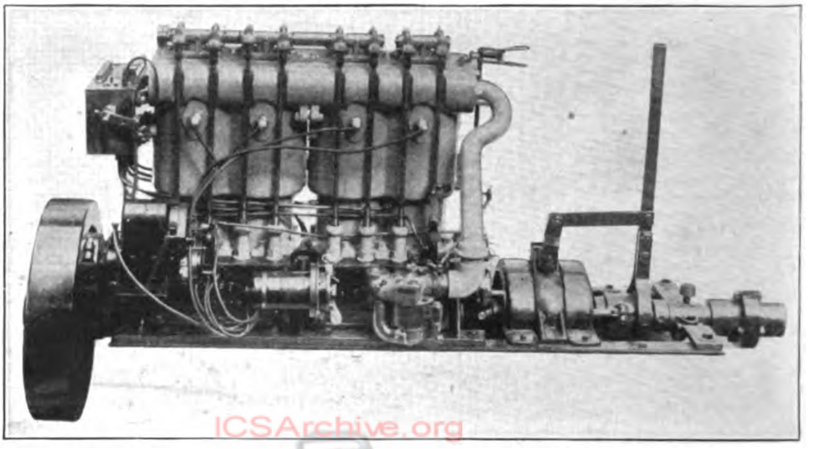


Fig. 22. Thirty-Horsepower Medium-Speed Marine Motor
Courtesy of Frisbie Motor Company, Middletown, Connecticut

inch stroke. The engine develops 25 h. p. when running at 600 revolutions per minute, and has a speed range of 150 to 850. Its weight complete is about 1000 pounds.

Frisbie. Fig. 22 is a medium-speed engine built by the Frisbie Motor Company of Middletown, Connecticut. This engine has four cylinders and is rated at 25 to 30 h. p. The construction

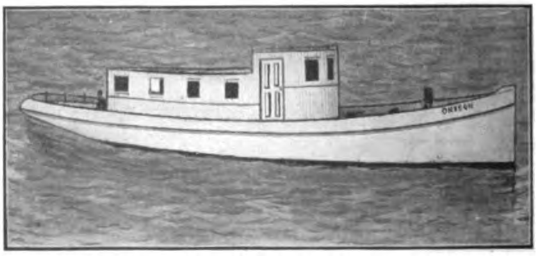


Fig. 23. Fish Boat
Courtesy of Automatic Engine Company, Bridgeport, Connecticut

should be especially noted, as the valves are in the cylinder heads, and are operated by vertical rods which are raised and lowered by a camshaft driven by gears from the engine shaft. The gears are not exposed, but run quietly in grease in a casing. On the sides of the cylinders, near the top, are the spark plugs with wires leading to the magneto at the left. The spark and throttle control levers are attached to the cylinder nearest the reverse clutch, so the engine can be easily handled.

Slow-Speed Motors. Slow-speed, heavy-duty motors are installed in towboats, lighters, fishing boats, Fig. 23, and in other craft owned by men who use their boats for commercial purposes.

Automatic. An example of a heavy-duty motor is shown in Fig. 24, and by comparing it with the high-speed motors, Figs. 19

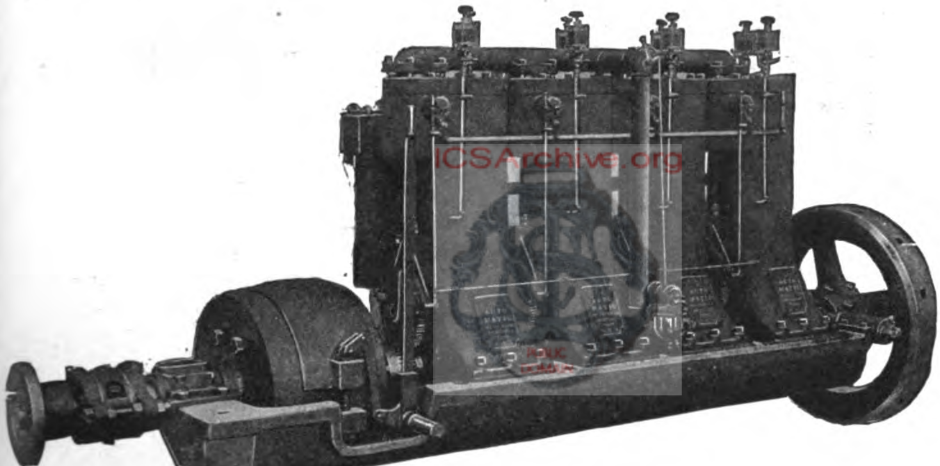


Fig. 24. One-Hundred-Horsepower Heavy-Duty Engine
Courtesy of Automatic Engine Company, Bridgeport, Connecticut

and 20, the differences in the two types are at once noticed. In the heavy-duty type, built by the Automatic Engine Company, Bridgeport, Connecticut, there are fewer cylinders, only four in the 100 h. p., but they are large in diameter, have a long stroke, and all the parts are heavy. The weight of the 100-h. p. engine in Fig. 24 is 11,800 pounds and it runs at 280 revolutions per minute, while the 225-h. p. high-speed motor in Fig. 19 weighs only 1460 pounds and runs at 1500 revolutions per minute.

Atlas. The engine, Fig. 25, is built by the Atlas Engine Company, Oakland, California. It is rated at 80 h. p., has three cylinders, and runs at 300 revolutions. It has a long stroke with cylin-

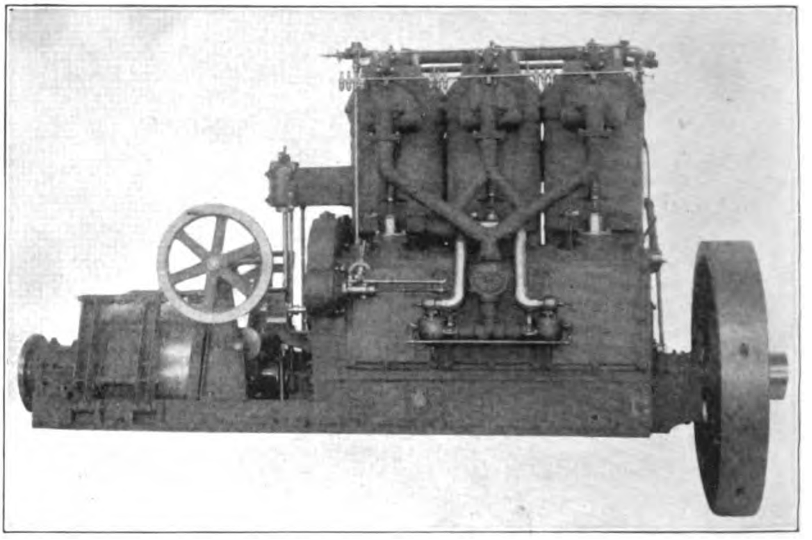


Fig. 25. Heavy-Duty 80-Horsepower Atlas Engine
Courtesy of Atlas Gas Engine Company, Oakland, California

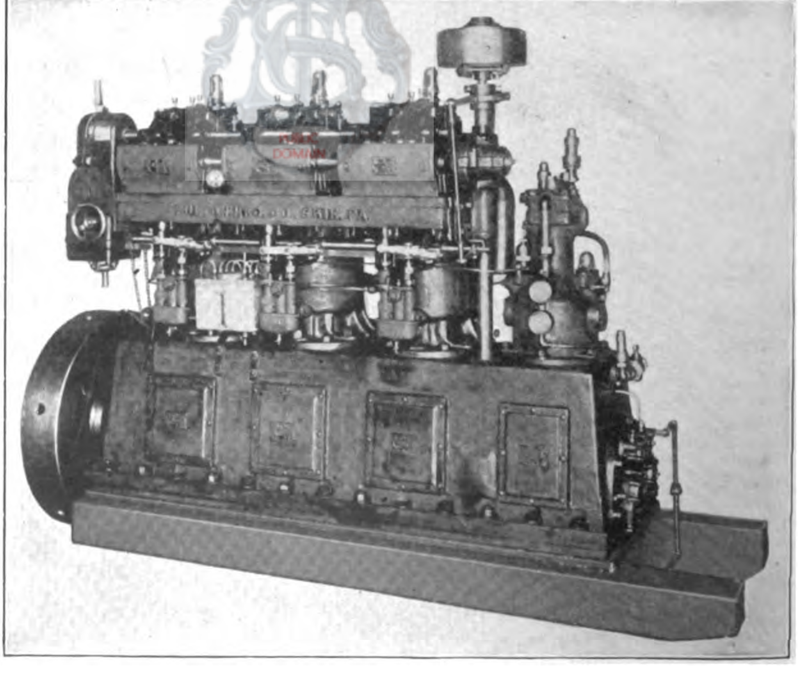


Fig. 26. Fifty-Horsepower Diesel-Fulton Engine
Courtesy of Fulton Manufacturing Company, Erie, Pennsylvania

ders of a large bore, and represents a type of engine much used for commercial purposes on the Pacific Coast. Make-and-break ignition is used, with an igniter lever which controls the time of the spark on all the cylinders at the same time. For operating the reverse gear, the wheel on the left is used instead of a lever, as is the practice on the Atlantic Coast. The tugboat, Fig. 3, is equipped with two 50-h. p. Atlas engines.

Diesel Engines. Diesel engines are primarily commercial engines, yet they have been installed in some large yachts, such as the Aelgdytha, Fig. 17, which has two of 180 h. p. each. When cheap oil is available, they are particularly adapted for cargo vessels, as they take up less space than the usual steam engine and boiler, and their running expenses are low. The East Asiatic Company, a company trading between Copenhagen, Denmark, and the Far East, after building two Diesel-engine ships found them so satisfactory for their trade that they ordered seven more, ranging in size from 7000 tons to 10,000 tons dead weight and driven by Diesel engines of 2500 to 4100 h. p.

Fulton. Fig. 26 shows a three-cylinder, four-cycle Diesel engine built by the Fulton Manufacturing Company, Erie, Pennsylvania. The engine shown is of special interest, as it is the smallest Diesel engine built in the United States. It is very economical in the consumption of fuel; in fact, the builders guarantee .55 pound of fuel per brake horsepower.

Referring to the figure above, on the left are the operating wheels, while on the right is the air compressor. Owing to the high cylinder compression, it is necessary to start on compressed air. At the right, mounted on a vertical shaft, is the governor which regulates the amount of oil from the fuel tanks.

Harris Valveless. Another engine operated on the Diesel principle is shown in Fig. 27 and was built by the Harris Patents Company, Philadelphia, Pennsylvania. This is of the two-cycle, step-piston type, built with two, four, six, or eight cylinders and with a multistage vertical air compressor driven from the crankshaft. The use of the step piston for air starting permits of a low air pressure—112 pounds up—and eliminates the danger of cracked cylinders, cylinder heads, and pistons caused by using cold high-pressure air in hot working cylinders in maneuvering. It also

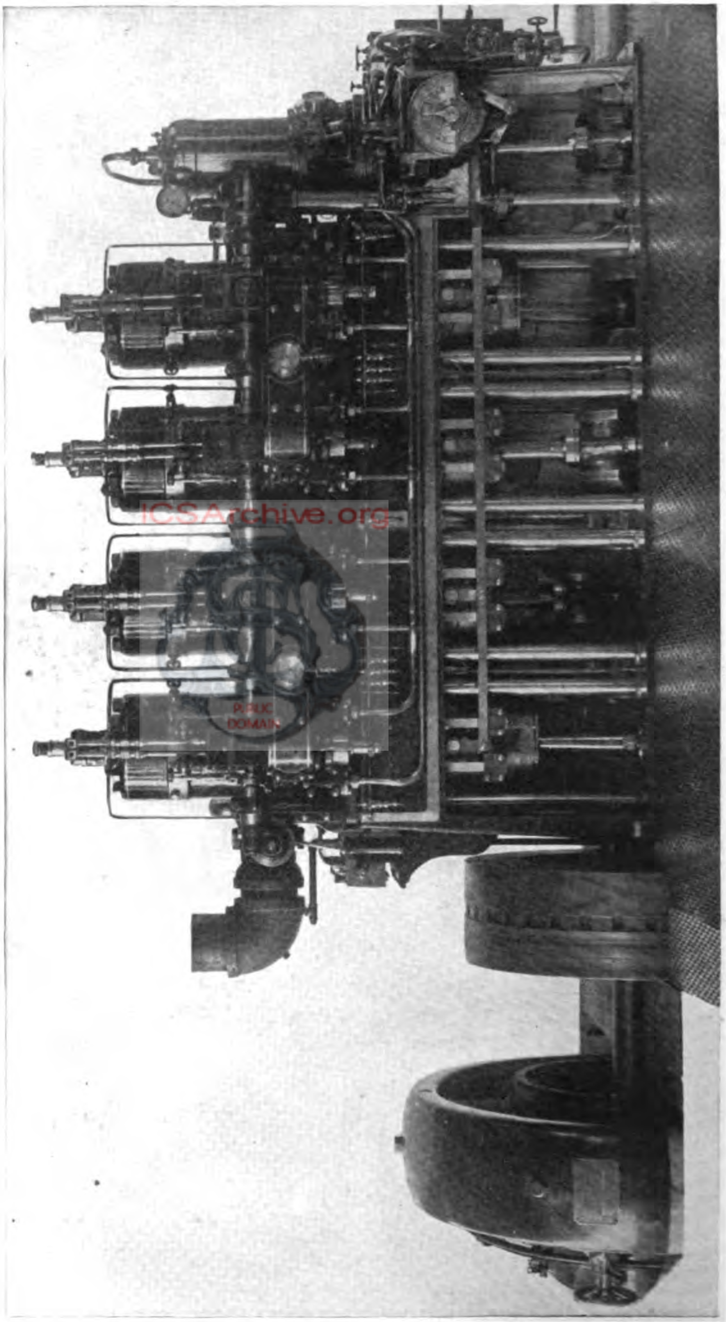


Fig. 27. Harris Valveless Engine, Diesel Principle, 240 Horsepower, Driving a Dynamo. Same Type of Engine Used for Marine Purposes
Courtesy of Harris Patents Company, Philadelphia, Pennsylvania

insures positive and quick starting, and enables the engine to be started under load, the same as a steam engine.

To reverse, it is not necessary to shift the camshaft. A single wheel, through interlocking devices, controls the air starting, fuel oil pumps, and atomizer admission for *start, stop, slow, go-ahead,* or *go-astern* orders and prevents any mistakes on the part of the engineer.

The engine may be started from stone-cold to full power in ten seconds. The fuel pumps act on the variable-stroke principle, controlled by the governor changing the fuel supply to suit the load requirements, instead of being governed by a finger acting on a sensitive check valve and by-passing and churning the oil in the supply pipe.

Bolinder. Although not a Diesel engine, yet having features in common, the engine, Fig. 28, built by the Bolinders Engine Company, New York, has been built for years in Stockholm, Sweden, and largely used in commercial craft in Europe. It is of the two-cycle, hot-bulb type, running on the lighter grades of residual oils and kerosene. No air compressor is required, the storage tanks for starting being charged by the cylinders when the engine is running. This engine is reversible without the use of air, although air is used for starting. The reversing is as follows: The clutch, Fig. 28, is thrown out by the lever at the right, and a reversing lever below it is pulled aft for going astern, thus causing the engine to slow down. A charge of oil is automatically injected at the proper stage of the cycle, and the movement of the piston is immediately reversed.

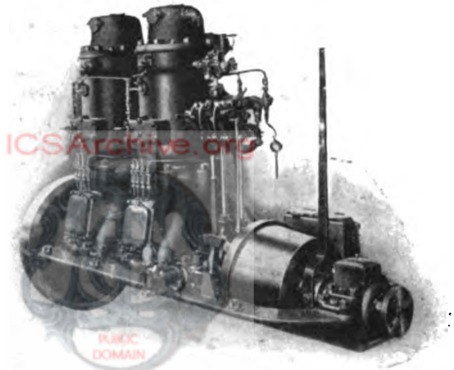


Fig. 28. Bolinder Crude-Oil Engine
Courtesy of The Bolinders Engine Company, New York City

Miscellaneous Types of Motors. In Fig. 29 is shown a portable motor which can be attached to the stern of an ordinary rowboat. The motor is started by turning the wheel at the top, the cylinder being forward of it, while the fuel tank is aft. The shaft is enclosed in the tube next to the stern and drives the propeller by bevel gears. In some makes the bevel gears are done away with, the propeller being driven by a flexible shaft.

Another type of motor is a vertical one which drives, by a chain and sprockets, a paddle wheel at the stern of the boat. This method of propulsion is only adopted when the water is very shallow.

Fig. 29. Waterman Outboard Motor
Courtesy of Waterman Marine Motor Company, Detroit, Michigan

MOTOR DETAILS AND ACCESSORIES

Motor cylinders are of close-grained cast iron, and in the large sizes are cast separately or in pairs, but in small sizes they may be all cast together or *en bloc*. If the cylinders are separate they are sometimes easier to machine and handle than when *en bloc*, although in the latter way the alignment of all is absolutely the same and no adjusting is necessary, as when cast singly.

Water Jackets. It is essential that the cylinder should be kept cool, and this is accomplished by a water jacket, Fig. 30. In many engines the jackets extend over the top or head of the cylinder, such a type being called a solid head. This type has advantages over those with a bolted-on cylinder cover, for in the former there is no chance for a leaky head or of stopping the water circulation in the

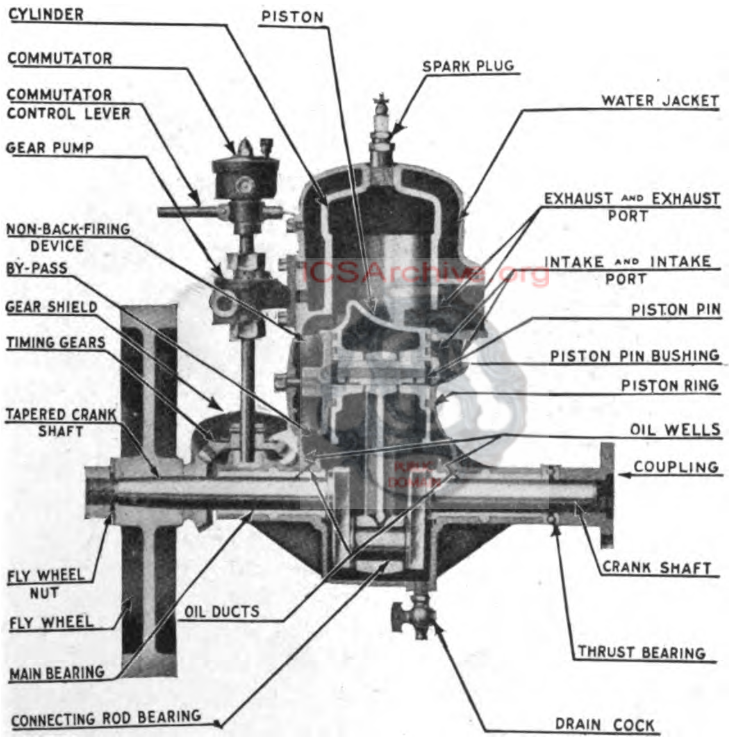


Fig. 30. Section of Two-Cycle Marine Engine
Courtesy of Gray Motor Company, Detroit, Michigan

head. Handholes are provided so that the jacket can be cleaned out, and cocks are supplied for drawing off the water.

In Fig. 31 is shown a cast-iron cylinder, which, instead of having the water jacket cast as an integral part of the cylinder, is provided with a copper jacket, water circulating in the space between the copper jacket and the cylinder. Should water freeze in the jacket and burst it, the only part that would have to be replaced would be the copper jacket, while, with the usual construction, an entire new cylinder would be necessary. Cylinders with copper jackets are built by the Waterman Marine Motor Company of Detroit, Michigan.

The quantity of water passing through the jacket should be such that the cylinder is kept warm. If the cylinder were kept cold there would be a loss of efficiency, that is, the engine would not supply the power which its rating would demand.

Fig. 31. Cast-Iron Cylinder with Copper Jacket, Disassembled
Courtesy of Waterman Marine Motor Company, Detroit, Michigan

Circulating Pumps. Water is forced through the jackets either by a centrifugal or by a plunger pump, the former being invariably used for large engines. Water is drawn from outside, forced through the jackets, and then discharged overboard again. The pump is driven from the crankshaft, and in many instances is of bronze.

Base. The cylinders are either cast long enough so as to be bolted directly to the cast-iron (sometimes aluminum or bronze for high-speed engines) base, or are bolted to a casting that in turn is fastened to the base. The castings have handholes which are large enough to give ready access to the connecting rod, crankshaft, and bearings.

Valves. The valves controlling the entrance of the charge into the cylinder in two-cycle engines have either two or three ports. In the former, on the up stroke of the piston the charge enters the crankcase through a check valve, which closes on the down stroke. In the three-port type, the check valve is not required.

In four-cycle engines the inlet and exhaust valves are arranged in one of two ways: First, the exhaust valve is cam-operated with the suction of the piston operating the inlet valve on the second or charging stroke; and second, the inlet and exhaust valves are mechanically operated. The latter arrangement is adapted for high-speed engines and the former for slow-speed heavy-duty. When the valves are on opposite sides of the cylinder, the cylinder is known as the **T** type, and when they are both on the same side it is called the **L** type, Fig. 32. In the former, two camshafts are required, while in the latter only one.

In another type the valves are inverted and seat directly in the top of the cylinder, an arrangement which necessitates either an overhead camshaft or valve lifters. The Frisbie Motor Company builds engines with valves in the cylinder head, as shown in Fig. 22 and at the right hand of Fig. 32; the valves are in cages which contain both the valve and its seat, the cages being easily removable.

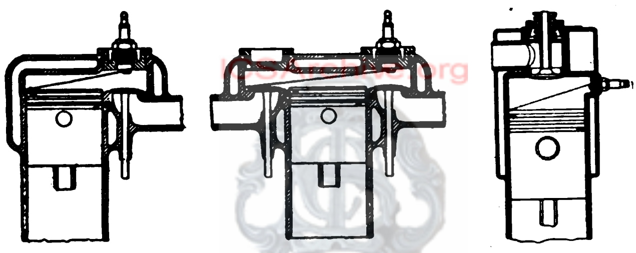


Fig. 32. Sections Showing L-Head, T-Head, and Straight-Head Cylinders
Courtesy of Frisbie Motor Company, Middletown, Conn.

It is most important that the valves be correctly timed, the exhaust valve opening soon enough to discharge the gases quickly, this valve closing before the inlet valve opens.

Ignition Systems. The ignition of the explosive mixture in the cylinders is accomplished by a hot torch, by making and breaking an electric current, or by a jump spark. In Diesel engines the fuel is forced into a cylinder which contains air compressed to such a high pressure that its temperature is above the ignition point of the fuel. When the fuel comes in contact with this compressed air, it ignites and the explosion forces the piston down, thus giving the power stroke.

Hot-Torch System. The hot-torch ignition system consists of heating an igniter plug on the cylinder head by a torch. When it is at the proper temperature, which takes from two to five minutes to reach, the explosive mixture enters the cylinder and is ignited when coming in contact with the hot igniter plug. After the engine has been started, the torch can be extinguished, as the combustion of the successive charges keeps the plug hot. The above system, in various modifications, has been extensively used in kerosene engines and those using the lower grades of semi-refined oils.

Make-and-Break, or Low-Tension System. In the make-and-break system a spark is produced in the combustion chamber of the cylinder by the breaking of an electric circuit. There are required a battery or a magneto for generating the current, a coil, and an igniter, as shown in Fig. 33. One of the advantages of this system is that it is not easily affected by dampness and is consequently largely used in open boats. Its disadvantages are that there are moving parts within the cylinder, and that the system is more difficult to apply to high-speed engines.

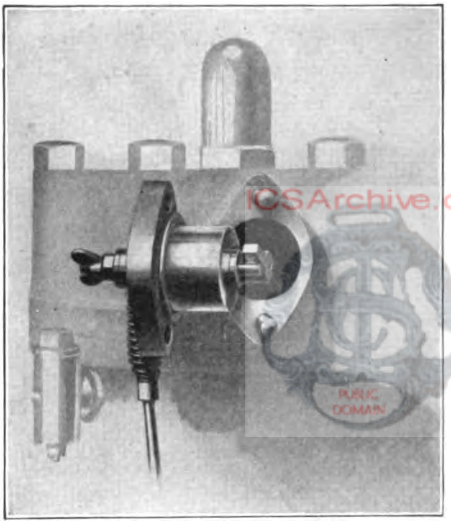


Fig. 33. Removable Igniter Plug
Courtesy of Standard Motor Construction Company, Jersey City, New Jersey

The current is led to a coil consisting of a core of soft-iron wires around which are wound several layers of heavy insulated copper wire. The current after passing through the coil goes to the terminals of the igniter, which consist of a fixed and a movable electrode—the latter being operated by the rise and fall of the rod shown at the left in Fig. 33. The igniter illustrated is fitted on engines built by the Standard Motor Construction Company, and can be readily removed without changing any of the adjustments. The contact points are tipped with platinum-iridium, which insures long wear and clean points. Large mica washers are used for insulation, and all movable parts are casehardened, so as to stand long usage.

Jump-Spark or High-Tension System. In the jump-spark system the current is transformed from primary or low tension to high tension (15,000 to 20,000 volts) by a spark coil, Fig. 34; then as a high-tension current it is led to the spark plug in the top of the cylinder, the current jumping across the gap between the points of the plug and, in so doing, creating a spark. It is evident that the spark must be controlled, otherwise there would be one continuous spark between the points of the plug. The controlling of the spark is accomplished by a timer.

Fig. 34. Jump-Spark Coil

Spark coils for high-tension work are different from those for low-tension in that they are covered with another winding of fine insulated copper wire. That is, they consist of a core of soft-iron wire, around which are wound a few layers of coarse copper wire, called the primary coil, on top of which are wound a great many layers of fine insulated copper wire, called the secondary, but not connected with the primary. When the low-voltage current is broken in the primary coil, a high-voltage current is induced in the secondary, and this goes to the spark plugs.


Fig. 35. Connecticut Plug Coil

Instead of having one coil for all the spark plugs, the Connecticut Telephone and Electric Company of Meriden, Connecticut, manufactures a combined plug and coil, Fig. 35, which is screwed into the cylinder just like an ordinary spark plug. The makers claim that no amount of water will affect the coil; in fact, a stream could be played over one without injuring it.

There are several high-tension systems on the market using high-tension magnetos. The simplest one uses the magneto only. Another is the dual system, the cylinders having two separate spark plugs—one for the batteries and the other for the magneto. Still another has only one plug for each cylinder, the batteries and magneto being so arranged that either can be used.

Magnetos. Magnetos are miniature dynamos and are driven from the engine by belts, gears, or by direct contact with the flywheel. The purpose of a magneto is to generate a current of electricity which takes the place of the one from the primary or storage batteries used for ignition. In Fig. 36 is shown a magneto, made by the Henricks Novelty Company, Indianapolis, Indiana, which can be friction driven; on the left end of the shaft will be noted a disk which bears against the flywheel of the motor.

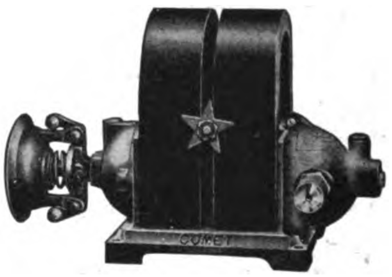


Fig. 36. Low-Tension Magneto

There are two kinds of magnetos, low- and high-tension; the former can be used either with jump-spark or make-and-break ignition, while the latter can be used only with the jump spark. By having the proper ratio of the revolutions of the shafts of a low-tension magneto and engine—say four to one—the engine can often be started without any batteries. When used for jump-spark ignition a spark coil and a timer are necessary.

High-tension magnetos, such as in Fig. 37, built by the Bosch Magneto Company, New York City, are only for jump-spark ignition and differ radically from the low-tension type, as neither a spark coil nor timer is required. In the high tension there are two windings, a high and a low, and a circuit breaker which breaks the circuit in the high-tension winding. By so doing, a current is induced in the secondary winding, which current goes to the spark plugs.

High-tension magnetos are gear or socket-and-chain driven from the engine shaft. They are more sensitive than the low-tension type, and have to be carefully protected from the weather. The engine can be started directly from them without batteries.

Timers and Distributors. It is evident that the time of ignition must be controlled in the jump-spark system, and this is accomplished by a *timer*, driven from the engine shaft, which completes the primary circuit between the battery or magneto and the spark coil at the proper instant at which the ignition of the charge in the cylinder should take place.

Instead of timers, *distributors* are sometimes used for distributing the current directly to the cylinders. Along this line a system of ignition has been developed by the Atwater Kent Manufacturing Works of Philadelphia, Pennsylvania, that is well adapted to heavy-duty engines, because of the uniformity of the spark; the spark is just as hot when the fly-wheel is turned over slowly as when running at full speed.

Fig. 37. Bosch Enclosed Type Magneto

In the Kent system, in addition to the usual batteries or magneto for generating the current, there is a unisparker, Fig. 38, consisting of a mechanical contact maker, a high-tension distributor, and a non-vibrating spark coil. The unisparker is driven from the engine shaft, giving one spark per revolution, the important feature in its construction being that it produces a spark of constant strength irrespective of the speed of the engine, and the battery circuit is never closed except at the instant of the spark. The motor can thus never stop so as to leave the ignition circuit closed if the switch is accidentally left on. As a result of the negligible current consumed, a set of ordinary dry cells will last for several weeks.

Fig. 38. Atwater-Kent Unisparker

Batteries. Dry or primary batteries are largely used for ignition systems. Many owners of motor boats start the engine on dry batteries and when it is running satisfactorily switch them off and run on the magneto. Sometimes wet batteries are used, but for convenience in handling the dry type is more popular.

Storage batteries either of the wet or dry type are often used, for they have a long life and can be recharged from the electric starting motor if the engine is equipped with one. They should not be placed in compartments below the floor where it is difficult to get at them, as fumes may be given off which, when confined and mixed with air, make an explosive mixture. The batteries should be in a readily accessible place, and be kept in an acid-proof box, so that no acid can ever come in contact with the wood work.

Piston and Piston Rings. The piston, which fits inside the cylinder, is made of cast iron, and has several grooves—often as many as four—in which rings are snapped, thus making a tight sliding surface between the piston and the cylinder walls.

The ends of the rings are sometimes cut at an angle, and then again with a step, so as to get a joint that will prevent the passing of any gas from the top to the bottom of the piston.

An improved type of ring, Fig. 39, manufactured by the McQuay-Norris Manufacturing Company, St. Louis, Missouri, consists of a two-piece concentric ring constructed so that the point of expansion in each piece is opposite that of the other.

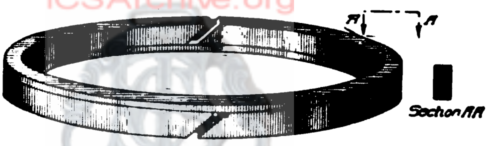


Fig. 39. Leak-Proof Piston Ring
Courtesy of McQuay-Norris Manufacturing Company

Governor. On engines of 20 h. p. and over many builders install a governor, which is connected to the throttle valve by levers. The governor allows changing the speed of the engine to any degree within its limits, at the same time preventing racing of the engine should the clutch be disengaged or the propeller wheel come off.

Starters. Motors of the smaller sizes are hand-started by turning the flywheel, or by sprocket wheels and chain operated by a crank, or by using a bar with a pawl on the end that fits in a wheel on the crankshaft. Large engines are started either by compressed air or by electric motors.

Air Starters. In an air-starting device as built by the Buffalo Gasoline Motor Company, the air is taken from a tank where it has previously been compressed, and enters a distributor, from which pipes lead to the check valves on the cylinders. Each valve is provided with a spring of sufficient tension to resist the suction stroke of the piston, and is timed so that pure air is alternately admitted to each cylinder until the explosion occurs and the engine starts. When the air is turned off, the valve is at once seated and there is no friction or wear when the engine is running. Some makes of motors can be started and reversed by compressed air.

Electric Starters. In Figs. 20 and 21 are shown electric starters consisting essentially of an electric motor which drives a metal belt running over a pulley on the engine shaft. In the starter, Fig. 21, built by the Leece-Neville Company, Cleveland, Ohio, there is a motor-generator (current for which is furnished by a storage battery) which turns the engine shaft until the engine is started. As soon as this occurs, the motor generator automatically becomes a generator and charges the storage battery back through the starting switch, thus keeping the battery always fully charged for use in starting or lighting the boat. When the battery is charged the starting switch is turned to the off position, thus letting the motor generator run idle.

Lubrication. *Kinds of Lubricants.* The lubrication of a motor calls not only for the best of lubricants but also for a system of feeding which will prevent the wearing or rubbing surfaces from becoming unduly hot. In a marine engine, where many surfaces have to be lubricated under a wide range of temperatures, no single kind of oil or grease can answer all requirements. For the bearings that are outside of the crankcase and are easy of access, grease is usually used. For the interior of the cylinder, where the piston rubs against the walls and a hot temperature prevails, an oil is required which has good lubricating qualities but which does not vaporize or carbonize.

Standard Motor System. A lubricating system which has proved economical in the consumption of oil, and at the same time properly lubricates the wearing parts, is the one on the engines of the Standard Motor Construction Company, Jersey City, New Jersey. A mechanical lubricator, Fig. 40, is mounted on the front of the engine above the flywheel, from which oil in a measured quantity is distributed directly to all the surfaces under a sufficiently high pressure to render such lubrication positive under every possible condition.

Detroit System. Large motors are generally supplied with mechanical oilers consisting of a small pump or pumps driven by the engine shaft, the pumps forcing the oil through pipes to the parts to be lubricated.

Fig. 41 is a force-feed oiler as manufactured by the Detroit Lubricator Company, Detroit, Michigan. The pump, which has mechanically operated valves, is attached to the top of a reservoir, and is driven either by a wheel belted to another wheel on the engine shaft or, if desired, by a ratchet. On the top of the reservoir will be noticed a glass cover through which can be watched the feeding of the oil. When once adjusted, the oiler feeds the proper amount of oil automatically, for as the speed of the engine increases, the quantity of oil fed increases also, and similarly when the engine slows down the supply decreases.

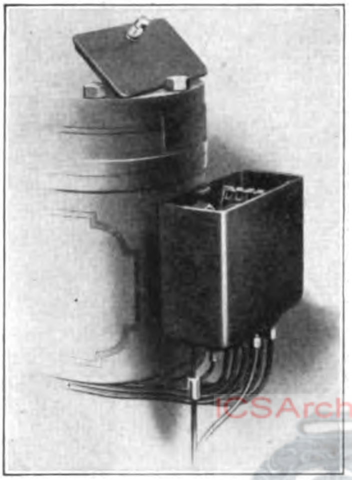


Fig. 40. Mechanical Lubricator
Courtesy of Standard Motor Construction Company

Lubricating the Parts. The cylinder gets oil at about the center, the oil entering at the level of the wrist pin when the piston is down, and spreading over the cylinder wall through grooves in the piston. Some of the oil enters the hollow wrist pin, to which the end of the connecting rod is fastened and lubricates it.

Fig. 41. Detroit Lubricator
Courtesy of The Detroit Lubricator Company, Detroit, Michigan

The crankpin can be lubricated either by a disk to which the oil is fed from the mechanical oiling system, or by the oil which drips from the wrist pin and is caught in a groove below the middle of the connecting rod and flows through a hole in this rod to the crankpin.

Instead of the above, some motors have oil in the crankcase and on the "go-ahead" side of the connecting rod have metallic dippers which dip into the oil, throwing it over the crankshaft, bearings, and other interior parts. This is known as the splash system. Care should be taken that the dippers just dip into the oil, for if there is too much oil thrown, the igniters or the spark plugs will become foul and the exhaust will be smoky.

Carbureters and Vaporizers. *Gasoline Carbureter.* There is a variety of carbureters on the market. In one type made for high-speed gasoline motors, the fuel is automatically controlled by a raised needle working automatically with the throttle. In another there is a jacket around the body of the carbureter through which the

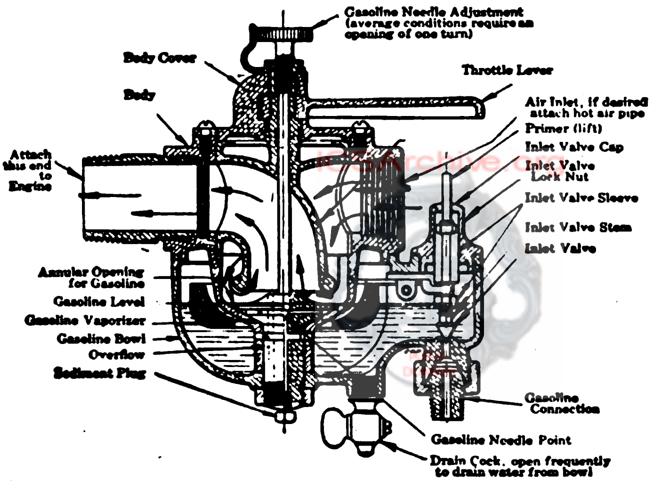


Fig. 42. Gasoline Carbureter
Courtesy of Gray Motor Company, Detroit, Michigan

exhaust gases from the cylinder pass, thus heating the gasoline and making it vaporize. Fig. 42 shows a section of one with an annular opening which spreads the gasoline over a large surface, thereby causing it to evaporate quickly. The throttle lever will be noted near the top, while at the top is the regulating wheel for the gasoline. By following the arrows from right to left it will be noticed how the air comes in contact with the gasoline and the mixture of air and gasoline passes on to the cylinders.

Kerosene Vaporizer. The ordinary gasoline carbureter will not satisfactorily vaporize kerosene, and hence, when kerosene is used a special vaporizer, as in Fig. 43, is required. After leaving the carbureter the kerosene and air pass through a nest of heated copper tubes and by so doing a vaporized mixture is secured. Just before the mixture enters the cylinders a few drops of water are mixed with it; the water, being drawn with the mixture into the cylinders,

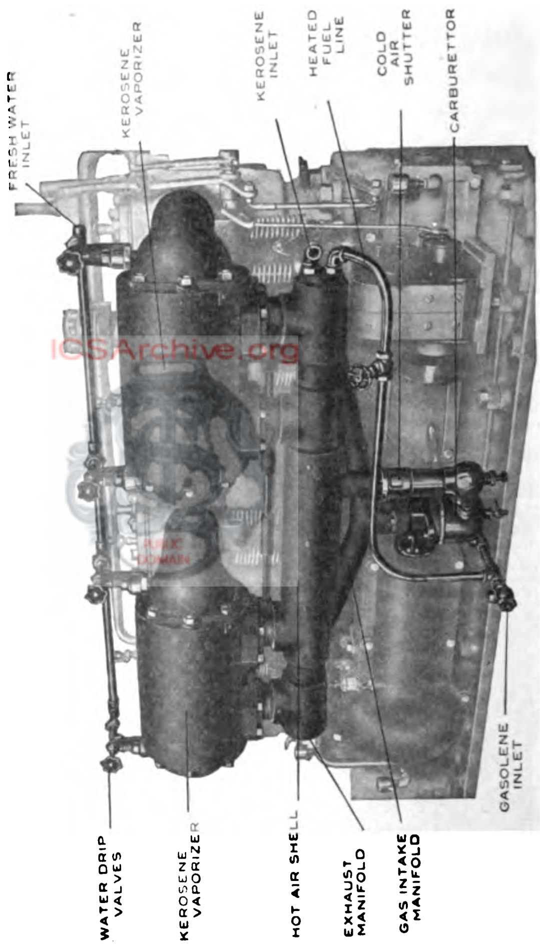


Fig. 43. Kerosene Vaporizer
Courtesy of Buffalo Gasoline Motor Company, Buffalo, New York

forms steam at the time of combustion, thus permitting high compression without pre-ignition. To heat the copper tubes, it is necessary to start the engine on gasoline and, after it is warmed up, to shut off the gasoline and turn on the kerosene.

Mufflers. In multicylinder engines the exhaust from the cylinders passes into a common manifold, from which it is led through a pipe to a muffler, or else the pipe is led overboard with its end preferably below the surface of the water. The muffling of the exhaust increases the back pressure on the pistons, and consequently reduces the power of the engine; but in ordinary running the reduction in power is small and is hardly worth considering when compared with the comfort of being in a boat with a quiet engine. In speed boats, where the maximum power is desired, the engines are run with free exhaust.

For under-water exhaust, the exhaust pipe can be led directly overboard or run aft to the stern of the boat. Launches and small cruisers often have under-water exhausts, but care must be taken that no water can flow back through the pipe into the cylinders.

For large power boats a muffler is absolutely essential, and it is common practice to build a false stack and place the muffler in it, giving a motor boat the appearance of a steam-engine-driven craft. (See the 110-foot motor yacht in Fig. 17.)

There are various methods used for muffling the exhaust, such as having the gases strike a series of vanes; having an expansion chamber in which the gases expand until the force of the explosion is lost; or, as in the Maxim Silencer, Fig. 44, so whirling the gases around through cylinders that they leave the muffler without any noise.

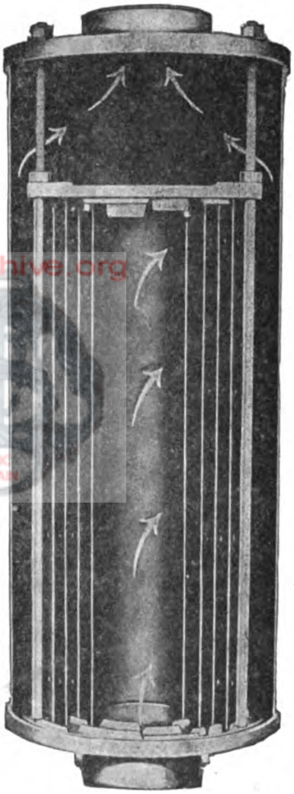


Fig. 44. Maxim Silencer
Wilcox, Crittenden, and Company, Middletown, Connecticut

Propeller Wheels. The diameter, pitch, and blade area of the propeller wheel depend on the type of boat and speed of the engine. For racing, an elliptical-shaped blade running at a high speed is required, while for towing, a wheel having blades with broad tips and running at a slow speed, with a pitch which gets a good grip on the water, is essential.

Pitch and Slip. The pitch is the distance a propeller would advance at each revolution if the medium in which it revolved was solid and if there was no slip; but water is not solid, hence at each revolution of the wheel it does not advance a distance equal to its pitch. The difference between the theoretical and the actual advance is the slip, which is given as a percentage, a fair average being about 15 per cent. The pitch ratio is the ratio of the pitch to the diameter.

Propeller Materials. Propellers are cast of manganese bronze, composition bronze, monel metal, and iron, the latter being used for large tugs and lighters and seldom for pleasure craft. Manganese bronze is the best material of all on account of its strength, toughness, and resistance to corrosion in salt water.

Fig. 45. Racing Propeller
Courtesy of Columbian Brass Foundry, Freeport, Long Island

Types. Good examples of wheels are shown in Figs. 45 to 48. Fig. 45 is for fast runabouts, Fig. 46 for cruisers and pleasure craft, Fig. 47 for towing, and Fig. 48 is of a special type for boats running in water where there is grass, the blades being so designed as to cut it.

Propellers are either right- or left-handed, the one selected depending on the direction the engine runs. To tell if a right-handed propeller is required, on facing the flywheel and looking aft, the flywheel should turn from right to left. If a left-hand propeller is wanted, the flywheel should turn from left to right. Or, on looking forward when standing aft of the stern, a right-hand wheel enters the water clockwise, or turning to the right; and a left-hand wheel enters turning to the left.

Reversible Propeller. For small engines, instead of having a solid wheel and a reversing gear, a reversible wheel is often installed, the blades being reversed by throwing a lever. In Fig. 49 is shown a three-blade reversing wheel as built by the Michigan Wheel Company of Grand Rapids, Michigan. The wheel is reversed by throwing the lever at the right, which can be placed anywhere along the

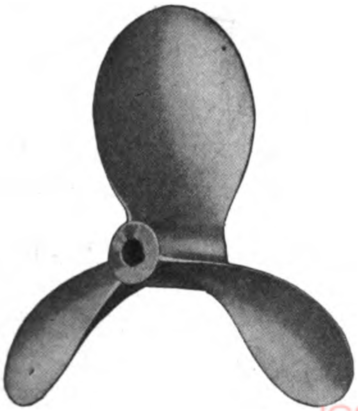


Fig. 46. Cruising Propeller
Courtesy of Columbian Brass Foundry, Freeport, Long Island

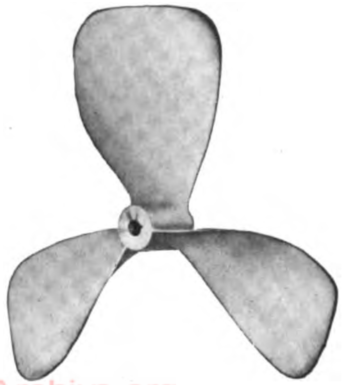


Fig. 47. Tow-Boat Propeller
Courtesy of Columbian Brass Foundry, Freeport, Long Island

shaft by adjusting the clamp collars. The blades are readily removed without disturbing any other part by removing the key in the quadrant and then pulling the lever forward, which unlocks the blades.

Fig. 48. Weedless Propeller
Courtesy of Columbian Brass Foundry, Freeport, Long Island

Steering Gear. *Rudder.* The steering gear consists of a rudder at the stern (in some speed boats there are two) from which ropes lead forward to the steering wheel. The shape of the rudder depends on the design of the boat. Shallow-draft boats cannot have deep rudders, and hence they must be broad, while for craft not limited by draft the greatest breadth should be a little below the water line. The strongest construction is obtained in cases where the rudder is supported by pintles resting in bearings on the sternpost. Rudders are balanced by having a part of their area forward of the rudder stock, which makes it easier to steer than when the rudder is not balanced. However, the rudder should not be too deep, as it will vibrate when the engine speeds up. In designing rudders, the location of the propeller wheel should be noted, for a boat with a wheel well forward and away from the rudder will steer much easier than one where the rudder and wheel are close together.

The rope connecting the rudder with the steering wheel should be strong and of the best material, and should run in as straight a line as possible. There are various devices for taking up the stretch in the rope due to constant use.

Steering Wheel. The steering wheel should be so located that the man at the wheel can have a free unobstructed view ahead and astern. In open launches it is invariably placed forward, and near it the levers controlling the throttle valve and the spark. In pleasure boats the wheel is often of the horizontal type, Fig. 50, mounted on

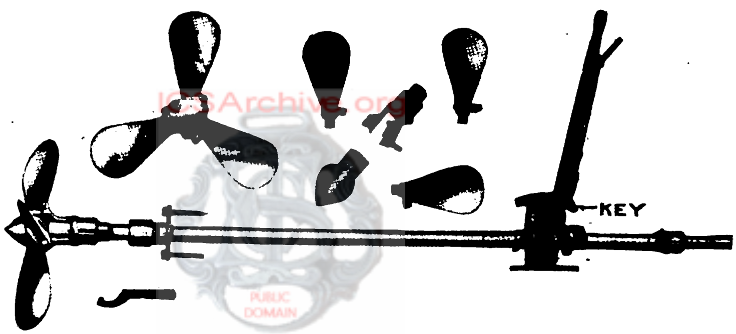


Fig. 49. Three-Blade Reversible Propeller
Courtesy of Michigan Wheel Company, Grand Rapids, Michigan

the deck as in Fig. 6. In runabouts, Fig. 7, and in speed boats the steering column is more often of the diagonal type, Fig. 51. In tugs, Fig. 3, and lighters, the wheel is forward in the pilot house.

Reversing Gear. It is evident that a boat cannot always go ahead. When it is necessary to go astern, the change in direction is accomplished by a reversing gear directly aft of the engine, which reverses the propeller shaft; or by a reversible propeller (see section on "Propeller Wheels"); or by reversing the engines, which in Diesel engines is done by compressed air.

Reverse gears consist briefly of a set of spur gears, a friction band, and an operating lever. In some makes, by throwing the lever forward, or toward the engine, the boat goes ahead; by bringing the lever to a perpendicular or neutral position the engine runs idle; and by pulling the lever backward, or aft, the boat will go astern.

Buffalo Reversing Gear. In Figs. 52 and 53 are shown the forward and aft views of the reversing gear used on the engines built by the Buffalo Gasoline Motor Company of Buffalo, New York. On the "go-ahead" motion the expanding wings, which are operated by two arms riding up a tapered cone, grip the inner surface of the drum, and the drum and all revolve as one solid shaft. On the "back-up" motion, the wings contract and the babbitted band which passes around the drum is tightened and holds the drum from revolving. The center driving gear is keyed to the crankshaft and meshes with a short planetary gear, which meshes with a long

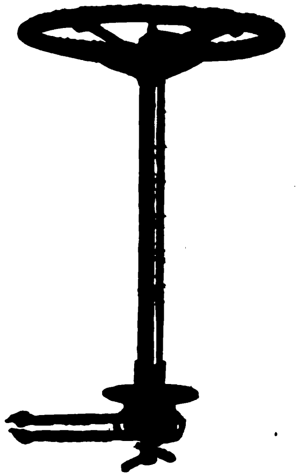


Fig. 50. Column Steering Wheel
Courtesy of Michigan Wheel Company, Grand Rapids, Michigan

Fig. 51. Diagonal Steering Wheel for Speed Boats
Courtesy of Michigan Wheel Company, Grand Rapids, Michigan

planetary gear, and which in turn meshes with the gear on the tail shaft.

Snow and Petrelli Reversing Gear. A duplex reversing gear for heavy-duty motors, made by the Snow and Petrelli Manufacturing Company of New Haven, Connecticut, is shown in Fig. 54. At each end there are two distinct friction clutches which operate as one, and by so doing the strain is taken off the gearing on the "go-ahead" drive. An important requisite in heavy-duty reverse gears is to have the reverse speed astern nearly equal to the speed ahead so that the boat can be run in either direction without throttling the motor. The gear in Fig. 54 is practically one to one—that is, the same for ahead or astern—a feature which insures promptness in driving the boat at full speed astern, as is often necessary.

Fig. 52. Forward View of Buffalo Reverse Gear
Courtesy of Buffalo Gasoline Motor Company, Buffalo, New York

INSTALLATION

As the types of motor boats and engines vary to such an extent it is impossible to give any hard-and-fast rules which will cover all the installation conditions that arise.

In the first place, take an arrangement drawing of the boat, Fig. 55, and draw on it—if this has not been already done—the engine, gasoline tank, batteries, muffler, and the sea connections for the water service to the engine. From such a drawing the lengths of the wire and pipe required can be scaled, and an idea secured of the space in the boat after the motor and accessories are installed, as well as the room available for passengers and freight.

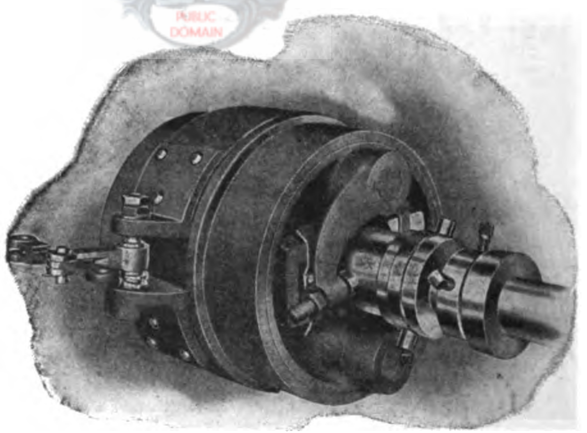


Fig. 53. After View of Buffalo Reverse Gear
Courtesy of Buffalo Gasoline Motor Company, Buffalo, New York

Installing the Engine. *Leveling the Hull.* The level of the hull should be checked up. This is done by placing a spirit level on the top of the keel, inside, and blocking the hull up in the fore-and-aft direction as may be required. When this is done, lay a smooth plank across the hull, place a spirit level on it, and block up the sides until level.

Line for Engine and Shaft. The next step is to run the line for the engine and shafting. Fasten a fine steel wire or strong string to a plank just aft of the sternpost and run the string through the center of the hole that has been bored for the shaft, the other end being fastened to the forward engine-room bulkhead or other suitable support. As an athwartship check, a plumb bob held over the string should point exactly to the center of the keel.

Engine Foundation. By measuring down from the wire or string a distance equal to the distance the base of the engine is from the center of its shaft, the necessary height of the engine foundation is obtained. The foundation should be of oak, extending forward and aft over several frames, and must be strongly bolted to the frames, Fig. 56, as well as to the center keelson if possible, thus distributing the vibration of the motor over a large area. Having been given the slope of the engine shaft, by means of the steel wire, the boat builder trims the foundation to the same angle.

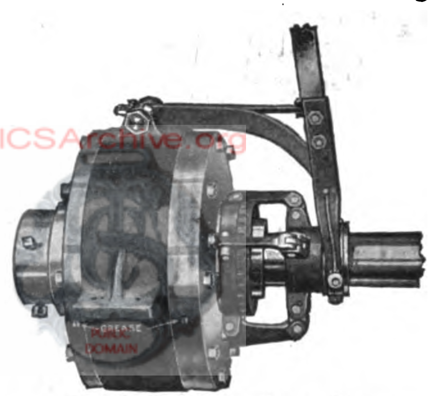


Fig. 54. Joe's Duplex Reverse Gear
Courtesy of Snow and Petrelli Manufacturing Company, New Haven, Connecticut

Aligning Engine and Propeller Shafts. When the foundation has been cut down the proper distance, the engine is put in place and the propeller shaft pushed through the stern bearing. If the alignment has been correct, the face of the flange on the engine shaft should be in the same plane as the one on the propeller shaft. If this is not true, go over the alignment again and then, if there has been no mistake, move the engine slightly and cut away the foundation or pack it up, depending on the way the two flange faces come together. The foundation must not be weakened by cutting away too much, nor must the engine be unduly packed up. When the flanges can be bolted together turn the engine over (open the cocks

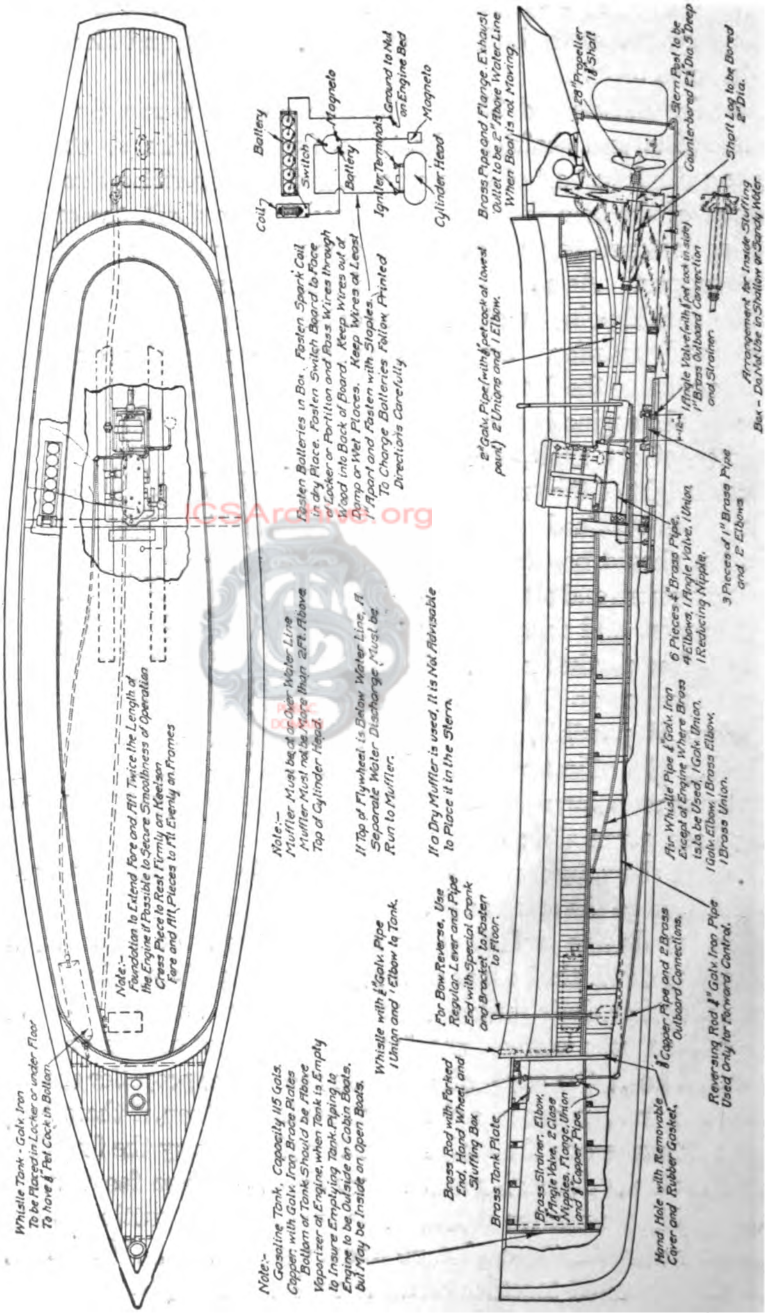


Fig. 55. Plan and Section of Motor Boat
Courtesy of Standard Motor Construction Company, Jersey City, New Jersey

on the cylinders so there is no compression), and if it does not turn freely, the shafting is out of line and the engine and the stern bearing must be humored so that the shafting can turn easily and without any binding.

Fuel System. After the engine is bolted to its foundation, the fuel system should be installed. The fuel tank, either of copper or galvanized iron, is preferably placed forward, and sufficiently high, with the outlet about six inches above the carbureter so that the fuel will readily flow to it. The piping should be of copper or brass, and should have two cocks in it—one near the tank and the other close to the engine. A strainer should also be in the line to

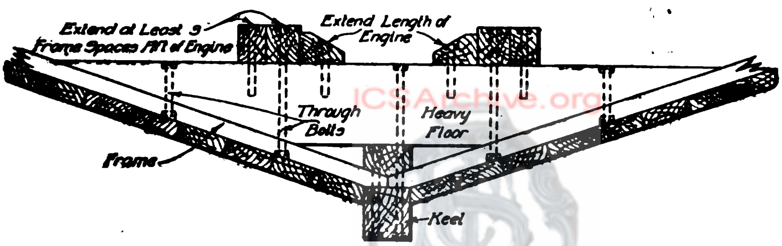


Fig. 56. Section of Hull Showing Details of Engine Foundation

prevent any dirt in the gasoline entering the carbureter. Great care should be taken to have the piping connections absolutely tight.

Exhaust Piping. The piping from the exhaust manifold on the engine to the muffler should be of wrought iron with as few bends as possible and, if practicable, it should be given a slope away from the engine. At the lowest point there should be a relief cock for drawing off any water that may collect. The muffler and piping should be kept at least two inches away from all woodwork. Care must be exercised in installing under-water exhausts so that no water can get into the cylinders.

Water Intake. The hole in the outside planking for the cooling-water intake should be so located as to have no sharp bends in the pipe (which is of brass) between the intake and the pump which circulates the water through the cylinder jackets. Over the intake fasten a scoop with small openings to prevent sticks and other floating debris from being drawn in. The overboard discharge from the cylinder jackets should be above the water line.

Piping Notes. Be sure that all pipes and fittings are cleaned out before connecting up. Have all pipe leads straight with few bends or elbows. Cut the threads carefully. Use shellac for the gasoline joints and white lead for the water joints.

Ignition System. The ignition system should be installed last, as the batteries, magneto, and accessories must not be handled roughly. The secondary wires should be kept from contact with the engine and piping, and also from water and oil. Have the batteries, spark coil, and all other parts affected by water well covered up. Directions for wiring are generally furnished with the engine, by the builder.

ENGINE OPERATIONS AND TROUBLES

Below are suggestions which should be followed, particularly if the engine has not been used for some time.

Starting Up. In cold weather, or if the motor has been idle for a long period, pour a small amount of gasoline in the priming cups, allowing it to enter the cylinders slowly.

Turn the engine over several times with the gasoline and electric connections off. Very often waste or other material gets caught on the shaft and prevents it from turning.

Go over the lubricating system, and be sure that oil will be fed to the parts when the engine is started.

Work the clutch on the reversing lever back and forth.

Open the sea cock so that water can be pumped through the cylinder water jackets.

Throw the switch on, so that the proper electric connection is made for generating sparks in the cylinders.

Do not leave tools, oil cans, and waste scattered about, as they are liable to be caught in the shaft or the moving parts when the engine starts.

Have near the engine a pailful of sand or a fire extinguisher, or preferably both.

When everything is ready, start the motor.

Under Way. Assuming the motor started, do not at once open wide the throttle valve, but do so gradually; by suddenly jumping the engine up to its maximum speed the parts are unduly strained.

If the engine runs smoothly do not tinker with it.

Turn down the grease cups on the bearings every hour or so if the bearings get hot, and note if the lubricating system is working properly.

If, when the engine has been running nicely, the carbureter suddenly begins to back-fire, the gasoline tank will be found to be empty or the supply pipe stopped up.

Should the engine stop suddenly the electric circuit may have been accidentally broken, or the supply of fuel stopped.

Control the engine chiefly with the throttle valve.

Docking. Do not come up to a dock at full speed and then quickly reverse, so as to stop the headway of the boat. Instead, start throttling the engine when a reasonable distance away.

If the boat is to be laid up, shut off the gasoline, close the sea cock, open the switch so as to break the electric circuit, close all oil cups, and, if it is winter, draw the water from the cylinder jackets.

Wipe off the engine and, if it will not be run again for some time, go over the unpainted parts with greasy waste.

Leave the engine in good condition so that it can be readily started up again.

Engine Troubles. If the engine cannot be made to run after four or five attempts, start looking for trouble. First see that the fuel is turned on, that the electric switch is thrown in, and that nothing has been caught in the shafting.

If the motor starts, then slows down, and finally stops, the supply of gas is choked or the batteries have given out.

Should the compression be weak, see if any of the spark plugs are loose, if the valves leak, or if there is a broken piston ring. If the valves leak they should be reground. This is done by taking out the valve, putting a grinding compound on the seat, replacing the valve, and turning it to the right and left until a clean smooth surface is on the valve face. Care should be taken in grinding that none of the compound used gets into the cylinder; if this happens the grinding material must be removed.

Search for Trouble. If the engine will not start after noting the above, begin a systematic search for trouble, beginning with the carbureter and then going over the ignition system.

Carbureter { Water in gasoline or in carbureter; air valve or needle valve out of adjustment.

Ignition System	Spark plugs dirty or short-circuited. Broken cable or poor connection at terminals. Vibrator out of adjustment or points burned. Weak batteries. Timer dirty. See that the magneto is revolving in the direction of rotation as stamped on the driving end. Open the circuit breaker and see that it is not flooded with oil, and that there is no oil on the contact points.
Engine Runs but Misses	Dirty spark plugs. Back-fires in carbureter, too lean a mixture. Valves leak. Batteries weak.
Engine Pounds	Engine not bolted firmly to its foundation. Piston ring broken. Shaft bearing loose. Connecting rod loose.
Cylinders Get Very Hot	Water circulation stopped. See if sea cock is opened, pump working, and the pipes not clogged up. Getting no oil.

Proper Mixture. To get the maximum power from the fuel it must be mixed with the correct amount of air. It is possible to have so much fuel and so little air that a very weak mixture is secured—hence see that the carbureter is so regulated that sufficient air is given the fuel.

Cold-Weather Starting. In cold weather hard starting may be caused by a fuel that is too heavy, consequently a light grade should be used in winter. Hard starting may also be caused by the sticking of the pistons in the cylinders. If such is the case, pour a little kerosene in the priming cups; let it run into the cylinder; rock the flywheel back and forth; and, when the piston moves, pour in some cylinder oil.

Engine Missing. Should an engine miss under full load with the throttle valve wide open, while it runs quietly at slow speed with the throttle partly open, the trouble is with the spark plugs, the points of which should be closer together, or the batteries are weak.

MOTOR BOAT TERMS, SIGNALS, AND REGULATIONS

Terms. *Port.* Left-hand side of a boat looking forward, indicated at night by a red light.

Starboard. Right-hand side of a boat looking forward, indicated at night by a green light.

Fathom. Six feet.

Heading. The direction of a boat's bow.

Knot. Sea mile of 6080 feet. Land mile 5280 feet.

Lee Side. The sheltered side or side opposite to the weather side.

Lay Her Course. A boat is said to lay her course if she keeps steadily on it, and does not fall off to the lee side or leeward.

Stand on Her Course. To keep on the same course.

Steerage Way. When a boat moves through the water with sufficient speed to enable her to be steered.

Under Way. Moving through the water.

Weather Side. The side on which the wind blows.

Weighing Anchor. Getting the anchor off the bottom and hoisting it on board.

Signals. When steam vessels are mentioned in the following rules motor boats are included.*

Whistle Signals. The whistle signals provided in these rules shall be sounded on an efficient whistle or siren sounded by steam or by some substitute for steam.

A short blast of the whistle shall mean a blast of about one second's duration, and a prolonged blast shall mean one of two to six seconds' duration.

One short blast signifies intention to direct course to own starboard, except when two steam vessels are approaching each other at right angles or obliquely, when it signifies intention of steam vessel which is to starboard of the other to hold course and speed.

Two short blasts signify intention to direct course to own port.

Three short blasts shall mean, "My engines are going at full speed astern". When vessels are in sight of one another, a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.

*From Pilot Rules, Steamboat Inspection Service, Edition April 28, 1914.

If a signal is not understood, blow at least four short, rapid blasts.

Answer a signal with the same signal.

Situations. When steam vessels are approaching each other head and head, that is, end on or nearly so, it shall be the duty of each to pass on the port side of the other; and either vessel shall give as a signal of her intention, one short and distinct blast of her whistle, which the other vessel shall answer promptly by a similar blast of her whistle, and thereupon such vessels shall pass on the port side of each other. But if the courses are so far on the starboard of each other as not to be considered as meeting head and head, either vessel shall immediately give two short blasts of her whistle, which the other vessel shall answer promptly by two similar blasts, and they shall pass on the starboard side of each other.

When a vessel is nearing a short bend or a curve in the channel she shall give one long blast of the steam whistle, which signal shall be answered by a similar blast, given by any approaching steam vessel that may be within hearing.

When steam vessels are moved from their docks or berths, and other boats are likely to pass from any direction toward them, they shall give the same signal as in the case of vessels meeting at a bend.

When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard side of the vessel ahead, she shall give one short blast of the steam whistle as a signal of such desire and, if the vessel ahead answers with one blast, she shall put her helm to port; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall put her helm to starboard; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals.

If two steam vessels are approaching each other at right angles or obliquely, so as to involve risk of collision, other than when one steam vessel is overtaking another steam vessel, the steam vessel which has the other on her port side shall hold her course and speed, and the steam vessel which has the other on her own starboard side shall keep out of the way of the other by directing her course to starboard so as to cross the stern of the other steam vessel, or, if necessary to do so, slacken her speed or stop or reverse.

When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessel shall keep out of the way of the sailing vessel.

Fog Signals. In fog, falling snow, or heavy rainstorm, whether by day or by night, signals shall be given as follows:

A steam vessel under way, except when towing other vessels or being towed, shall sound, at intervals of not more than one minute on the whistle or siren, a prolonged blast.

A steam vessel when towing other vessels shall sound, at intervals of not more than one minute on the whistle or siren, three blasts in succession, namely, one prolonged blast followed by two short blasts.

A vessel towed may give at intervals of not more than one minute on the foghorn, a signal of three blasts in succession, namely, one prolonged blast followed by two short blasts, and she shall not give any other.

A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

Distress Signals. In the daytime, continuous sounding of whistle or firing guns. At night, rockets sent up at short intervals, firing guns, or continuous sounding of whistle.

Regulation of Motor Boats.* The words motor boats where used in this Act shall include every vessel propelled by machinery and not more than sixty-five feet in length except tugboats propelled by steam. The length shall be measured from end to end over the deck excluding sheer: *Provided,* That the engine, boiler, or other operating machinery shall be subject to inspection by the local inspectors of steam vessels, and to their approval of the design thereof, on all said motor boats, which are more than forty feet in length, and which are propelled by machinery driven by steam.

*Abstract of Circular 236, Bureau of Navigation, Act of Congress, June 9, 1910.

SEC. 2. Motor boats subject to the provisions of this Act shall be divided into classes as follows:

Class One. Less than twenty-six feet in length.

Class Two. Twenty-six feet or over and less than forty feet in length.

Class Three. Forty feet or over and not more than sixty-five feet in length.

SEC. 3. Every motor boat in all weathers from sunset to sunrise shall carry the following lights, and during such time no other lights which may be mistaken for those prescribed shall be exhibited.

(*a*) Every motor boat of Class One shall carry the following lights:

First. A white light aft to show all around the horizon.

Second. A combined lantern in the fore part of the vessel and lower than the white light aft, showing green to starboard and red to port, so fixed as to throw the light from right ahead to two points abaft the beam on their respective sides.

(*b*) Every motor boat of Classes Two and Three shall carry the following lights:

First. A bright white light in the fore part of the vessel as near the stem as practicable, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side. The glass or lens shall be of not less than the following dimensions:

Class Two. Nineteen square inches.

Class Three. Thirty-one square inches.

Second. A white light aft to show all around the horizon.

Third. On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side. On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side. The glasses or lenses in the said lights shall be of not less than the following dimensions on motor boats of

Class Two. Sixteen square inches.

Class Three. Twenty-five square inches.

On and after July 1, 1911, all glasses or lenses prescribed by paragraph (*b*) of Section 3 shall be fresnel or fluted. The said lights shall be fitted with inboard screens of sufficient height and so set as to prevent these lights from being seen across the bow and shall be of not less than the following dimensions on motor boats of

Class Two. Eighteen inches long.

Class Three. Twenty-four inches long.

Provided, That motor boats as defined in this Act, when propelled by sail and machinery or under sail alone, shall carry the colored lights suitably screened but not the white lights prescribed by this section.

SEC. 4. (*a*) Every motor boat under the provisions of this Act shall be provided with a whistle, or other sound-producing mechanical appliance capable of producing a blast of two seconds or more in duration, and in the case of such boats so provided a blast of at least two seconds shall be deemed a prolonged blast within the meaning of the law.

(*b*) Every motor boat of Class Two or Three shall carry an efficient foghorn.

(*c*) Every motor boat of Class Two or Three shall be provided with an efficient bell, which shall be not less than eight inches across the mouth, on board of vessels of Class Three.

SEC. 5. Every motor boat subject to any of the provisions of this Act, and also all vessels propelled by machinery other than by steam, more than sixty-five feet in length, shall carry either life preservers or life belts, or buoyant cushions, or ring buoys, or other device, to be prescribed by the Secretary of Commerce and Labor, sufficient to sustain afloat every person on board, and so placed as to be readily accessible. All motor boats carrying passengers for hire shall carry one life preserver of the sort prescribed by the regulations of the board of supervising inspectors for every passenger carried, and no such boat while so carrying passengers for hire shall be operated or navigated except in charge of a person duly licensed for such service by the local board of inspectors. No examination shall be required as the condition of obtaining such a license, and any such license shall be revoked or suspended by the local board of inspectors for misconduct, gross negligence, recklessness in navigation, intemperance, or violation of law on the part of the holder and, if revoked, the person holding such license shall be incapable of obtaining another such license for one year from the date of revocation; *Provided*, That motor boats shall not be required to carry licensed officers except as required in this Act.

SEC. 6. Every motor boat, and also every vessel propelled by machinery other than by steam, more than sixty-five feet in length, shall carry ready for immediate use the means of promptly and effectually extinguishing burning gasoline.

Notes as Regards the Above Act. The lights provided for in Section 3 are running lights for motor boats and are not in conflict with the anchor lights and lights for pilot and fishing vessels. Thus the anchor light for motor boats on inland waters will remain as prescribed in Article II of the Act of June 7, 1897, as follows:

Art. II. "A vessel under one hundred and fifty feet in length when at anchor shall carry forward, where it can best be seen, but at a height not exceeding twenty feet above the hull, a white light, in a lantern so constructed as to show a clear, uniform, and unbroken light visible all around the horizon at a distance of at least one mile."

If a motor boat through temporary disablement of the machinery or lack of gasoline finds it necessary to proceed under sail, the white lights should be extinguished and she should proceed with her colored lights only.

The aft light should be higher and so placed as to form a range with the forward light, and should be clear of house awnings and other obstructions.

The law does not specify the size of lights to be carried on motor boats of Class One. However it is suggested that the illuminated portion of such lights or lenses should not be less than three inches in diameter.

No size or style of whistle, foghorn, or bell (except the bell for Class Three) is prescribed, provided it is available and sufficient for the use for which it is intended.

A mouth whistle capable of producing a blast of two seconds or more in duration which can be heard for at least one-half a mile has been held to be in compliance with the law.

Foghorns cannot take the place of whistles on motor boats of Classes Two and Three.

Every motor boat not carrying passengers for hire must have life preservers or life belts or buoyant cushions, or ring buoys, or other device, which should be of types approved by the Board of Supervising Inspectors, sufficient to sustain afloat every person on board. This includes members of the crew, children, and babies.

In addition, the Department authorizes life preservers and buoyant cushions for motor boats not carrying passengers for hire under the following conditions: Each life preserver or buoyant cushion shall be capable of sustaining afloat for a continuous period of twenty-four hours an attached weight so arranged that whether the said weight be submerged or not there shall be a direct downward gravitation pull upon such life preserver or cushion of at least 20 pounds. If a buoyant cushion is furnished for more than one person, its capacity must be proportionately greater.

No such life preservers or buoyant cushions stuffed or filled with granulated cork or other loose granulated material and no pneumatic life preservers or cushions will be approved.

Motor boats carrying passengers for hire shall carry one life preserver of the sort prescribed by the Board of Supervising Inspectors for every passenger carried, and the person in charge must be duly licensed.

Motor boats hired at launch liveries carrying any person in addition to the person operating are construed as carrying passengers for hire.

Although no specific means are prescribed besides the usual fire extinguishers, yet salt or sand (preferably the two mixed) should be kept in a pail ready for immediate use, the pail being marked—
USE ONLY IN CASE OF FIRE

Motor boats propelled otherwise than by steam of above 15 gross tons, carrying freight or passengers for hire, but not engaged in fishing as a regular business, are subject to inspection whether under or over 65 feet in length.

The only officer required to be carried on motor boats within the contemplation of the Act of June 9, 1910, is the licensed operator provided for in the act.

All motor boats of over five net tons engaged in trade must be documented; that is to say, licensed by the collectors of customs. Vessels under five net tons are not documented in any case. The license of the vessel obtained from the collector of customs (designated a document) is additional to and must not be confounded with the license required for the operator of a motor boat.

Documented vessels must have name and home port on stern and name on each bow. Tonnage measurement is necessary only in case of vessels requiring to be documented.

Motor boats are required to have on board two copies of the pilot rules to be observed by them, which will be furnished by local inspectors of steam vessels on request.

GLOSSARY

GLOSSARY

THE following glossary of automobile terms is not intended in any sense as a dictionary and only words used in the articles themselves have been defined. The definitions have been made as simple as possible, but if other terms unfamiliar to the reader are used, these should be looked up in order to obtain the complete definition.

A

A. A. A.: Abbreviation for American Automobile Association.

Abrasive: Any hard substance used for grinding or wearing away other substances.

Absorber, Shock: See "Shock Absorber".

Accelerate: To increase the speed.

Acceleration: The rate of change of velocity of a moving body. In automobiles, the ability of the car to increase in speed. Pickup.

Accelerator: Device for rapid control of the speed for quick opening and closing of the throttle. Usually in the form of a pedal, spring returned, the minimum throttle opening being controlled by the setting of the hand throttle.

Accessory: A subordinate machine that accompanies or aids a more important machine; as, a horn is an accessory of an automobile.

Accumulator: A secondary battery or storage battery. It usually consists of chemically prepared lead plates combined with an acid solution. Upon being charged with an electric current from a primary source, a chemical change takes place which enables the plates in their turn to give a current of electricity when used as a source of power, the plates at the same time returning to their original chemical state.

Acetone: A liquid obtained as a by-product in the distillation of wood alcohol, and used in connection with reservoirs for storing acetylene for automobile lights, as it dissolves many times its own volume of acetylene gas.

Acetylated Alcohol: Alcohol which has been denatured by the addition of acetylene, which also increases its fuel value. See "Alcohol, Denatured".

Acetylene: A gaseous hydrocarbide used as an illuminant; is usually generated for that purpose by the action of water on calcium carbide.

Acetylene Generator. A closed vessel in which acetylene gas may be produced by the action of water on calcium carbide and which supplies the gas under uniform pressure.

Acetylene Lamp: A lamp which burns acetylene gas.

Acetylite: Calcium carbide which has been treated with glucose. It is used to obtain a more uniform and slower production of acetylene gas than can be obtained with the untreated calcium carbide.

Acid: In connection with automobiles the term usually means the liquid or electrolyte used in the storage battery. See "Electrolyte".

Acid Cure. Method of rapid vulcanization of rubber without heat. Used in tire repairs. The agent is sulphur chloride.

Acidimeter. An instrument for determining the purity of an acid.

Active Material: Composition in grids that forms plates of a storage battery. It is this material in which the chemical changes occur in charging and discharging.

Adapter: Device by which one type of lamp burner may be used instead of the one for which the lamp was designed. Usually a fitting by which a gas or oil lamp may be converted into an electric lamp.

Adhesion: That property of surfaces in contact by virtue of which one of them tends to stick to the other. It is used as synonymous with friction. The adhesion of wheels acts to prevent slipping.

Adjustment: The slackening or tightening up of parts to compensate for wear, reduce friction, or secure better contact.

Admission: In a steam engine, the letting in of the steam to the cylinder; in gas engine, the letting in of mixture of gas and air to the cylinder.

Advanced Ignition: Usually called *advancing the spark*. Setting the spark of an internal-combustion motor so that it will ignite the charge at an earlier part of the stroke.

Advance Sparking: A method by which the time of occurrence of the ignition spark may be regulated, by completing the electric circuit at the earlier period.

Advancing the Spark: See "Advanced Ignition".

Aerodynamics: The science of atmospheric laws, i.e., the effects produced by air in motion.

After-Burning: Continued burning of the charge in an internal-combustion engine after the explosion.

After-Firing: An explosion in the muffler or exhaust passages.

A-h: Abbreviation for *ampere hour.*

Air Bottle: A portable container holding compressed air or carbon dioxide for tire inflation.

Air-Bound: See "Air Lock".

Air Compressor: A machine for supplying air under pressure for inflating tires, starting the motor, etc.

Air Cooled: Cooled by air direct. Usually referring to the cylinder of an engine, whose heat caused by the combustion within it is carried away by air convection and radiation.

Air Cooling: A system of dispersing by air convection the heat generated in the cylinder of an internal-combustion motor.

Air Intake: An opening in a carbureter to admit air.

Air Leak: Entrance of air into the mixture between carbureter and cylinder.

Air Lock: Stoppage of circulation in the water or gasoline system caused by a bubble of air lodging in the top of a bend in the pipe.

Air Pump: A pump operated by the engine or by hand to supply air pressure to the oil tank or gasoline tank; sometimes called *pressure pump*.

Air-Pump Governor: A device to regulate the speed of the air pump so as to give a uniform air pressure.

Air Resistance: The resistance encountered by a surface in motion. This resistance increases as the square of the speed, which makes it necessary to employ four times as much power in order to double a given speed.

Air Tube: See "Pneumatic Tire".

Airless Tire: Name of special make of nonpuncturable resilient tire.

A. L. A. M.: Abbreviation for Association of Licensed Automobile Manufacturers, now out of existence.

A. L. A. M. Horsepower Rating: The horsepower rating of an automobile found by the standard horsepower formula approved by the Association of Licensed Automobile Manufacturers. Since the dismemberment of this organisation, the formula is usually called the S.A.E. rating. This formula is h.p. = bore of cylinder (in inches) squared × No. of cylinders ÷ 2.5, at a piston speed of 1000 r.p.m.

Alarm, Low-Water: See "Low-Water Alarm".

Alcohol: A colorless, volatile, inflammable liquid which may be used as fuel for internal-combustion engines.

Alcohol, Denatured: Alcohol rendered unfit for drinking purposes by the addition of wood alcohol, acetylene, and other substances.

Alignment: The state of being exactly in line. Applied to crankshafts and transmission shafts and to the parallel conditions of the front and rear wheels on either side.

Alternating Current: Electric current which alternates in direction periodically.

Ammeter: An instrument to measure the values of current in an electric circuit directly in amperes. Also called *ampere meter*.

Amperage: The number of amperes, or current strength, in an electric circuit.

Ampere: The practical unit of rate of flow of electric current, measuring the current intensity.

Ampere Hour: A term used to denote the capacity of a storage battery or closed-circuit primary battery. A battery that will deliver three amperes for six hours is said to have an eighteen-ampere-hour capacity.

Ampere Meter: See "Ammeter".

Angle-Iron Underframe: An underframe constructed of steel bars whose cross section is a right angle.

Anneal: To make a metal soft by heating and cooling. To draw the temper of a metal.

Annular Gear: A toothed wheel upon which the teeth are formed on the inner circumference.

Annular Valve: A circular valve having a hole in the center.

Annunciator: An installation of electric signals or a speaking tube to allow the passengers in an enclosed car to communicate with the driver.

Anti-Freezing Solution: A solution to be used in the cooling system to prevent freezing in cold weather; any harmless solution whose freezing point is somewhat below that of water may be used.

Anti-Friction Metal: Various alloys of tin and lead used to line bearings, such as Babbitt metal, white metal, etc.

Anti-Skid Device: Any device which may be applied to the wheels of a motorcar to prevent their skidding, such as tire coverings with metal rivets in them, chains, etc.

Apron: Extensions of the fenders to prevent splashing by mud or road dirt.

Armature: In dynamo-electric machines, the portion of a generator in which the current is developed, or in a motor, the portion in which the current produces rotation. In most generators in automobile work, the armature is the rotating portion. In magnetic or electromagnetic machines the armature is the movable portion which is attached to the magnetic poles.

Armature Core: The iron portion of the armature which carries the windings and serves as part of the path for the magnetic flux.

Armature Shaft: The shaft upon and with which the armature rotates.

Armature Winding: Electrical conductors, usually copper, in an armature, and in which the current is generated, in case of a generator, or in which they produce rotation in a motor.

Artillery Wheel: A wheel having heavy wood spokes.

Aspirating Nozzle: An atomizing nozzle to make the liquid passing through it pass from it in the form of a spray.

Assembled Car: A car whose chief parts, such as engine, gearset axles, body, etc., are manufactured by different parts makers, only the final process of putting them together being carried out in the car-making plant.

Atmospheric Line: A line drawn on an indicator diagram at a point corresponding with the pressure of the atmosphere.

Atmospheric Valve: See "Suction Valve".

Atomizer: A device by which a liquid fuel, such as gasoline, is reduced to small particles or to a spray; usually incorporated in the carbureter.

Auto: (1) Popular abbreviation for automobile. (2) A Greek prefix meaning self.

Auto-Bus: An enclosed motor-driven public conveyance, seating six or more people; usually has a regular route of travel.

Autocar: A motorcar or automobile; a trade name for a particular make of automobile.

Auto-Cycle: See "Motorcycle".

Autodrome: A track especially prepared for automobile driving, particularly for races.

Autogenous Welding: See "Welding, Autogenous".

Auto-Igniter: A small magneto generator or dynamo for igniting gasoline engines, the armature of which is connected with the flywheel by gears or by friction wheels, so that electric current is supplied as long as the engine revolves.

Autoist: One who uses an automobile.

Automatic Carbureter: A vaporizer or carbureter for gasoline engines whose action is entirely automatic.

Automatic Cut-Out: See "Cut-Out, Automatic".

Automatic Spark Advance: Automatic variation of the instant of spark occurrence in the cylinder. Mechanical advancing and retarding of the spark to correspond with and controlled by variations in crankshaft speed.

Auto-Meter: Trade name for special make of combined speedometer and odometer.

Automobile: A motor-driven vehicle having four or more wheels. Some three-wheeled vehicles are properly automobiles, but are usually called *tricars*.

Automobilist: The driver or user of an automobile.

Auto Truck: A motor-driven vehicle for transporting heavy loads; a heavy commercial car.

Auxiliary Air Valve: Valve controlling the admission of air through the auxiliary air intake of a carbureter.

Auxiliary Air Intake: Opening through which additional air is admitted to the carbureter at high speeds.

Auxiliary Exhaust: Ports cut through cylinder walls to permit exhaust gases to be released from the cylinder when uncovered by the piston. These are sometimes used as an additional scavenging means for the regular exhaust valves.

Auxiliary Fuel Tank: See "Fuel Tank, Auxiliary".

Auxiliary Spark Gap: See "Spark Gap, Outside".

Axle: The spindle with which a wheel revolves or upon which it revolves.

Axle, Cambered: An axle whose ends are slanted downwards to camber the wheels.

Axle, Channel: An axle which is U-shaped in cross section.

Axle, Dead: Solid, fixed, stationary axle. An axle upon which the wheels revolve but which itself does not revolve.

Axle, Dropped: An axle in which the central portion is on a lower level than the ends.

Axle, Floating: A full-floating axle. A live axle in which the shafts support none of the car weight, but serve only to turn the wheels.

Axle, I-Beam: An axle whose cross section is in the shape of the letter I.

Axle, Live: An axle in which are comprised the driving shafts that carry the power of the motor to the driving wheels.

Axle, Semi-Floating: A live axle in which the driving shafts carry a part of the car weight as well as transmitting the driving torque.

Axle, Three-Quarters Floating: A live axle in which the shafts carry a part of the weight of the car, but less than that carried by the semi-floating axle. It is intermedinated by a floating axle and the semi-floating axle.

Axle, Trussed: An axle in which downward bending is prevented by a truss.

Axle, Tubular: An axle formed of steel tubing. Usually applied to the front axles, but sometimes used in referring to tubular shafts of rear axles.

Axle Casing: That part of a live axle that encloses the driving shafts and differential and driving gears. Axle housing.

Axle Housing: See "Axle Casing".

Axle Shaft: The member transmitting the driving torque from the differential to the rear wheels.

B

Babbitt: A soft metal alloy used for lining the bearings of shafts.

Back-Firing: An explosion of the mixture in the intake manifold or carbureter caused by the communication of the flame of explosion in the cylinders. Usually due to too weak a mixture. Popping.

Back Kick: The reversal of direction of the starting, caused by back-firing.

Backlash: The play between a screw and nut or between the teeth of a pair of gear wheels.

Back Pressure: Pressure of the exhaust gases due to improper design or operation of the exhaust system.

Baffle Plate: A plate used to prevent too free movement of a liquid in the container. In a gas engine cylinder, a plate covering the lower end of the cylinder to prevent too much oil being splashed into it. The plate has a slot through which the connecting rod may work.

Balance Gear: See "Differential Gear".

Balancing of Gasoline Engines: Insuring the equilibrium of moving parts to reduce the vibration and shocks.

Ball-and-Socket Joint: A joint in which a ball is placed within a socket recessed to fit it, permitting free motion in any direction within limits.

Ball Bearing: A bearing in which the rotating shaft or axle is carried upon a number of small steel balls which are free to turn in annular paths, called *races*.

Balladeur Train: A French name for a sliding change-speed gear.

Barking: The sound made by the explosions caused by after-firing.

Base Bearing: See "Main Bearing".

Base Explosion: See "Crankcase Explosion".

Battery: A combination of primary or secondary cells, as dry cells or storage cells.

Battery, Dry: See "Dry Battery".

Battery, Storage: See "Accumulator".

Battery Acid: The electrolyte in a storage battery.

Battery-Charging Plug: Power terminals to which the leads of a storage battery may be connected for charging the battery.

Battery Gage: (1) Voltmeter or ammeter or voltammeter for testing the specific gravity of the electrolyte in a secondary battery.

Battery Syringe: A syringe used to draw out a part of the electrolyte or solution from a storage battery cell to test its density and specific gravity.

Baume: A scale indicating the specific gravity or density of liquids and having degrees as units. Gasoline of a specific gravity of .735 has a gravity of 61 degrees Baumé.

Bearing: A support of a shaft upon which it may rotate.

Bearing, Annular Ball: A ball bearing consisting of two concentric rings, between which are steel balls.

Bearing, Ball: A bearing in which the rotating shaft and the stationary portion of the bearings are separated from sliding contact by steel balls. A steel collar fitted to the shaft rolls upon the balls, which in turn roll upon steel collar attached to the stationary portion of the bearing.

Bearing, Cup and Cone: A ball bearing in which the balls roll in a race, which is formed between a cone-shaped fixed collar and a cup-shaped shaft collar.

Bearing, Main: The bearing in which rotates the crankshaft of an engine.

Bearing, Plain: A bearing in which the rotating shaft is in sliding contact with the bearing supporting it.

Bearing, Radial: A bearing designed to resist loads from a direction at right angles to the axis of the shaft.

Bearing, Roller: A bearing in which the journal rests upon, and is surrounded by, hardened steel rollers which revolve in a channel or race surrounding the shaft.

Bearing, Thrust: A bearing designed to resist loads or pressures parallel with the axis of the shaft.

Bearing Cap: That portion of a plain bearing detachable from the stationary portion, and which holds the bearing bushing and shaft.

Bearing Surface: The projected area of a bearing in a perpendicular plane to the direction of pressure.

Beau de Rochas Cycle: The four-stroke cycle used in most internal-combustion engines. This cycle was proposed by M. Beau de Rochas and put into practical form by Dr. Otto. See "Four-Cycle".

Belt and Clutch Dressing: A composition to be applied to belts and clutches to prevent them from slipping.

Belt Drive: A method of transmitting power from the engine to the countershaft or jack shaft by means of belts.

Benzine: A petroleum product having a specific gravity between that of kerosene and gasoline. Its specific gravity is between 60 degrees and 65 degrees Baumé.

Benzol: A product of the distillation of coal tar. Coal tar bensine. Used as a rubber solvent and in Europe as a motor fuel.

Berline Body: A limousine automobile body having more than two seats in the back part.

Bevel-Gear: Gears the faces of whose teeth are not parallel with the shaft, but are on a beveled edge of the gear wheel.

Bevel-Gear Drive: Method of driving one shaft from another at an angle to the first. The chief method of transmitting the drive from the propeller shaft to the rear axle shafts.

B. H. P.: An abbreviation for brake horsepower.

Bicycle: A two-wheeled vehicle propelled by the pedaling of the rider.

Binding Posts: See "Terminals".

Bleeder: A by-pass in the sight-feed of a mechanical oiling system by which the oil delivered through that feed is allowed to pass out instead of going to the bearings.

Blister: A defect in tires caused by the separation of the tread from the fabric.

Block Chain: A chain used in automobiles, bicycles, etc., of which each alternate link is a steel block.

Blow-Back: The backward rushing of the fuel gas through the inlet valve into the carbureter.

Blower Cooled: A gas engine cooled by positive circulation of air maintained by a blower.

Blow-Off: A blow-out caused by the edge of the bead of tire becoming free from the rim and allowing the tube to protrude through the space thus formed.

Blow-Out: The rupture of both the inner tube and outer casing of a pneumatic tire.

Blow-Out Patch: See "Patch, Tire Repair".

Body: (1) The superstructure of an automobile; the part that resembles and represents the body of a horse-drawn vehicle. (2) In oils, the degree of viscosity. The tendency of drops of oils to hang together.

Body Hangers: Attachments to or extensions of the frame for holding the body of the vehicle. They should be properly called frame hangers.

Boiler: A vessel in which water is evaporated into steam for the generation of power.

Boiler, Fire-Tube: A tubular steam boiler in which the end plates are connected by a number of open ended thin tubes, the spaces around which are filled with water, the hot gases passing through the tubes.

Boiler, Flash: A steam boiler in which steam is generated practically instantaneously. There is practically no water or steam stored in the boiler. A flash generator.

Boiler, Water-Tube: A steam boiler in which the water is carried in metal tubes, around which the hot gases circulate.

Boiler Alarm: See "Low-Water Alarm".

Boiler Covering: A non-conducting substance used as a covering for boilers to prevent loss of heat by radiation.

Boiler-Feed Pump: An automatic and self-regulating pump for supplying a boiler with feed water.

Boiler-Feed Regulator: A device to make the feed-water supply of the boiler automatic.

Bonnet: (1) The hood or metallic cover over the front end of an automobile. See "Hood". (2) The cover over a pump-valve box, or a slide-valve casing. (3) A cover to enclose and guide the tail end of a steam-engine-valve spindle or the cover of a piston-valve casing. (4) The pan underneath the engine in an automobile.

Boot: A covering to protect joints from dirt and water or to prevent the leakage of grease. (2) Space provided for baggage at the rear of a car.

Bore: The inside diameter of the cylinder.

Boss: An enlarged portion of a part to give a point for attachment of another part.

Bottom: The meshing of gears without clearance.

Bow Separator: A part to prevent chafing of the bows of a top when folded.

Boyle's Law of Gases: A law defining the volume and pressure of gases at constantly maintained temperatures. It states that the volume of a gas varies inversely as the pressure so long as the temperature remains the same; or, the pressure of a gas is proportional to its density.

Brake: An apparatus for the absorption of power by friction, and by clamping some portion of the driving mechanism to retard or stop the forward motion of the car.

Brake, Air-Cooled: A brake whose parts are ridged to present a large surface for transferring to the air the frictional heat generated in them.

Brake, Band: A brake which contracts upon the outside of a drum attached to some part of the driving mechanism.

Brake, Constricting Band: A form of brake applied by tightening a band around a pulley or drum.

Brake, Differential: A brake acting upon the differential gear.

Brake, Double-Acting: A brake which will hold when the drum is rotating in either direction.

Brake, Drum, and Band: See "Brake, Band".

Brake, Emergency: A brake intended to be used in case the service brake does not act to a sufficient extent.

Brake, Expanding-Band: A drum brake in which the braking force is exerted by a band forced outward against the inner rim of a pulley.

Brake, External-Contracting: A brake consisting of a drum affixed to a rotating part, the outer surface of which is encircled by a contracting band.

Brake, Foot: A brake designed to be operated by the driver's foot. A pedal brake. Usually the service brake.

Brake, Front-Wheel: A brake designed to operate on the front wheels of the car.

Brake, Gearset: A brake designed to act on the transmission shaft and attached to the gearbox.

Brake, Hand: A brake designed to be operated by means of a hand lever. Usually the emergency brake.

Brake, Hub: A brake consisting of a drum secured to one of the wheels. This is the usual type.

Brake, Internal: A brake in which an expanding mechanism is contained within a rotating drum, the expansion bringing pressure to bear on the drum.

Brake, Internal-Expanding: A brake consisting of a drum, against the inside of which may be expanded a band or a shoe.

Brake, Motor: A brake in an electric vehicle which acts upon the armature shaft of the motor.

Brake, Service: A brake designed to be used in ordinary driving. It is usually operated by the driver's foot.

Brake, Shoe: A brake in which a metal shoe is clamped against a revolving wheel.

Brake, Transmission: A brake designed to act upon the transmission shaft.

Brake, Water-Cooled: A brake through which water may be circulated to carry off the frictional heat.

Brake Equalizer: A mechanism applied to a system of brakes operated in pairs to assure that each brake shall be applied with equal force.

Brake Horsepower: The horsepower supplied by an engine as shown by the application of a brake or absorption dynamometer.

Brake Housing: A casing enclosing the brake mechanism.

Brake Lever: The lever by which the brake is applied to the wheel.

Brake Lining: The wearing surface of a brake; usually arranged to be easily replaced when worn.

Brake Pedal: Pedal by which the brake is applied.

Brake Pull Rod: A rod transmitting the tension from the lever or pedal to the movable portion of the brake proper.

Brake Ratchet: A device by which the brake lever or brake pedal can be set in position and retained there; usually consists of a notched quadrant with which a movable tongue on the lever head or pedal engages.

Brake Rod: The rod connecting the brake lever with the brake.

Brake Test: A test of a motor by means of a dynamometer to determine its power output at different speeds.

Braking Surface: The surface of contact between the rotating and stationary parts of a brake.

Braze: To join by brazing.

Brazing: The process of permanently joining metal parts by intense heat.

Breaker Strip: A strip of canvas placed between the tread and body of an outer tire casing to increase the wearing qualities.

Breather: An opening in the crankcase of a gas engine to permit pressure therein to remain equal during the movement of the pistons.

British Thermal Unit. The ordinary unit of heat. It is that quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at the temperature of greatest density of water.

Brougham Body: A closed-in automobile body having windows at the side doors, and in front, but with no extension of the roof over the front seat.

Brush Holder: In electrical machinery, an arrangement to hold one end of a connection flexible in contact with a moving part of the circuit.

B. T. U.: Abbreviation for ***British Thermal Unit.***

Buckboard: A four-wheeled vehicle in which the body and springs are replaced by an elastic board or frame

Buckling: Irregularities in the shape of the plates of storage cells following a too rapid discharge.

Bumper: (1) A contrivance at the front of the car to minimize shock of collision; it consists of plungers working in tubes and gaining elasticity from springs. (2) A bar placed across the end of a car, usually the front end, to take the shock of collision and thus prevent damage to the car itself. A rubber or leather pad interposed between the axle and frame of a car.

Burner, "Torch" Igniter: A movable auxiliary vaporizer for starting the fire in steam automobile burners.

Bushing: A bearing lining. Usually made of anti-friction metal and capable of adjustment or renewal.

Bus-Pipe: A manifold pipe.

Butterfly Valve: A valve inserted in a pipe, usually circular and of nearly the same diameter as the pipe, designed to turn upon a spindle through its diameter and thus shut off or permit flow through the pipe. Usually employed for throttle valves and carbureter air valves.

Buzzer: (1) A name sometimes applied to the vibrator or trembler of a jump-spark ignition coil. (2) A device used in place of a horn, and consisting of a diaphragm which is made to vibrate rapidly by an electromagnet.

By-Pass: A small valve to provide a secondary passage for fluids passing through a system of piping.

C

C: Abbreviation for a centigrade degree of temperature.

Calcium Carbide: A compound of calcium and carbon used for the generation of acetylene by the application of water.

Calcium Chloride: A salt which dissolved in water is used as an anti-freezing solution.

Cam: A revolving disk, irregular in shape, fixed on a revolving shaft so as to impart to a rod or lever in contact with it an intermittent or variable motion.

Cam, Exhaust: A cam designed to operate the exhaust of an engine.

Cam, Ignition: A cam designed to operate the ignition mechanism. In magnetos it operates the make-and-break device.

Cam, Inlet: A cam designed to operate the inlet valve of an engine.

Camber: (1) The greatest depth of curvature of a surface. (2) The amount of bend in an axle designed to incline the wheels.

Camber of Spring: The maximum distance between the upper and lower parts of a spring under a given load.

Cambered Frame: A narrowing of the front of a motor car to permit of easier turning.

Cam Gear: The gear driving the camshaft of a gas engine. In a four-cycle engine this is the same as the two-speed gear.

Camshaft: A shaft by which the valve cams are rotated; also known as the *secondary shaft*.

Camshaft, Overhead: The camshaft carried along or above the cylinder heads, to operate overhead valves.

Camshaft Gears: The gears or train of gears by which the camshaft is driven from the crankshaft. Half-time gears, timing gears, distribution gears.

Canopy: An automobile top that can not be folded up.

Capacity of a Condenser: The quality of electricity or electrostatic charge. Of a storage battery, the amount of electricity which may be obtained by the discharge of a fully charged battery. Usually expressed in ampere hours.

Cape Hood: An automobile top which is capable of either being folded up or extended.

Car: A wheeled vehicle.

Carbide: See "Calcium Carbide".

Carbide Feed: A type of acetylene generator in which the calcium carbide is fed into the water.

Carbon Bridge: Formation of soot between points of spark plug.

Carbon Deposit: A deposit upon the interior of the combustion chamber of a gasoline engine composed of carbonaceous particles from the lubricating oil, too rich fuel mixture, or road dust.

Carbon Remover: A tool or solution for removing carbon deposits from the cylinder, piston, or spark plug of a gasoline engine.

Carbonization: The deposit of carbon.

Carbureter: An appliance for mixing an inflammable vapor with air. It allows air to be passed through or over a liquid fuel and to carry off a portion of its vapor mixed with the air, forming an explosive mixture.

Carbureter, Automatic: A carbureter so designed that either the air supply alone or both the air and gasoline supplies are regulated automatically.

Carbureter, Constant-Level: A carbureter the level of the gasoline in which is maintained automatically at a constant height. A float-feed carbureter.

Carbureter, Exhaust-Jacketed: A carbureter whose mixing chamber is heated by the circulation of exhaust gas.

Carbureter, Multiple-Jet: A carbureter having more that one spray nozzle or jet.

Carbureter, Water-Jacketed: A carbureter whose mixing chamber is heated by the circulation of water from the cooling system.

Carbureter Float: A buoyant part of the carbureter designed to float in the gasoline and connected to a valve controlling the flow from the fuel tank, designed to maintain automatically a constant level of the gasoline in the flow chamber.

Carbureter Float Chamber: A reservoir containing the float and in which a constant level of fuel is maintained.

Carbureter Jet: The opening through which liquid fuel is ejected in a spray from the standpipe of a carbureter nozzle.

Carbureter Needle Valve: A valve controlling the flow of fuel from the flow chamber to the standpipe.

Carburuter Nozzle: See "Carbureter Jet".

Carbureter Standpipe: A vertical pipe carrying the nozzle.

Carburetion: The process of mixing hydrocarbon particles with the air. The action in a carbureter.

Cardan Joint: A universal joint or Hooke's coupling.

Cardan Shaft: A shaft provided with a Cardan joint at each end.

Casing: The shoe or outer covering of a double-tube automobile tire.

Catalytic Ignition: See "Ignition,Catalytic".

Cell: One of the units of a voltaic battery.

Cell, Dry: See "Dry Cell".

Cell, Storage: See "Accumulator".

Cellular Radiator: A radiator in which the openings between the tubes are in the form of small cells. The same as a *honeycomb radiator*.

Cellular Tire: A cushion tire which is divided into compartments or cells.

Center of Gravity: That point in a body, which, if the body were suspended freely in equilibrium, would be the point of application of the resultant forces of gravity acting upon the body.

Center Control: The location of the gear-shift and emergency brake levers of a car in the center of a line parallel to the front of the front seat.

Centigrade Scale: The thermometer scale invented by Celsius. Used universally in scientific work.

Century. In automobiling, a hundred-mile run.

C. G. S. System: Abbreviation for centimeter-gram-second system of measurement; the standard system in scientific work.

Chain, Drive: A heavy chain by which the power from the motor may be transmitted to the rear wheels of an automobile.

Chain, Roller: A sprocket chain, the cross bars of whose links are rollers.

Chain, Silent: See "Silent Chain".

Chain, Tire: A small chain fastened about the tire to increase traction and prevent skidding.

Chain Wheel: A sprocket wheel for the transmission chains of a motor-driven vehicle.

Change-Speed Gear: See "Gear, Change-Speed".

Change-Speed Lever: See "Lever, Change-Speed".

Charge: The fuel mixture introduced into the cylinder of a gas engine. The act of storing up electric energy in an accumulator.

Charging: The passing of a current of electricity through a storage cell.

Charles' Law of Gases: See "Gases, Gay Lussac's Law of".

Chassis. The mechanical features of a motor car assembled, but without body, fenders, or other superstructure not essential to the operation of the car.

Chauffeur: In America this term means the paid driver or operator of a motor car. The literal translation from the French means stoker or fireman of a boiler.

Check, Steering: See "Steering Check".

Check Valve: An automatic or non-return valve used to control the admission of feed water in the boiler, etc.

Choke: The missing of explosions or poor explosions due to too rich mixture.

Circuit, Primary: See "Primary Circuit".

Circuit, Secondary: See "Secondary Circuit".

Circuit Breaker: A device installed in an electric circuit and intended to open the circuit automatically under predetermined conditions of current flow.

Circulating Pump: A pump which keeps a liquid flowing through a series of pipes which provides a return circuit. In a motor car, water and oil circulation is maintained by circulating pump.

Circulation Pump: A mechanically operated pump by which the circulation of water in the cooling system is maintained.

Circulating System: The method or series of pipes through which a continuous flow of water or oil is maintained and in which the liquid is sent through the system over and over.

Clash Gear: A sliding change-speed gear.

Clearance: (1) The distance between the road surface and the lowest part of the under-body of an automobile. (2) The space between the piston of an engine when at the extremity of its stroke, and the head of the cylinder.

Clearance, Valve: See "Valve Clearance".

Clearance Space: The space left between the end of the cylinder and the piston plus the volume of the ports between the valves and the cylinder.

Clevis: The fork on the end of a rod.

Clevis Pin: The pin passing through the ends of a clevis and through the rod to which the clevis is joined.

Clincher Rim: A wheel rim having a turned-in edge on each side, forming channels. Into this the edge or flange of the tire fits, the air pressure within locking the tire and rim together.

Clincher Tire: A pneumatic tire design to fit on a clincher rim.

Clutch: A device for engaging or disconnecting two pieces of shafting so that they revolve together or run free as desired.

Clutch Cone: A clutch whose engaging surfaces consist of the outer surface of the frustrum of one cone and the inner surface of the frustrum of another.

Clutch, Contracting-Band: A clutch consisting of a drum and band, the latter contracting upon the former.

Clutch, Dry-Plate: A clutch whose friction surfaces are metal plates, not lubricated.

Clutch, Expanding-Band: A clutch consisting of a drum and band, the latter expanding within the former.

Clutch, Jaw: A clutch whose members lock end to end by projections or jaws in one entering corresponding depressions in the other.

Clutch, Multiple-Disk: A clutch whose friction surfaces are metal plates or disks, alternate disks being attached to one member and the rest to the other member of the drive.

Clutch Brake: A device designed to stop automatically the rotation of the driven member of a clutch after disengagement from the driving member.

Clutch Lining: The wearing surface of a clutch. This may be easily removed and replaced when worn.

Clutch Pedal: The pedal by which the clutch may be disengaged, engagement being obtained automatically by means of a spring.

Clutch Spring: A spring arranged to either hold a clutch out of gear or throw it into gear.

Coasting: The movement of the car without constant applications of the motive power, as in running downhill with the aid of gravity or on the level, through the momentum obtained by previous power applications.

Cock, Priming: A small cock, usually operated by a lever, for admitting gasoline to the carbureter to start its action.

Coil, Induction: See "Spark Coil".

Coil, Non-Vibrator: A coil so designed that it will supply a sufficient spark for the ignition with one make and break of the primary circuit.

Coil, Primary: See "Primary Coil".

Coil, Secondary: See "Secondary Spark Coil".

Coil, Spark: See "Spark Coil".

Coil, Vibrator: A spark coil with which is incorporated an electromagnetic vibrator to make and break the primary circuit.

Coil Vaporizer: An auxiliary vaporiser to assist in starting a steam boiler. It is a coil of tubing into which liquid gasoline is admitted and burned to start the generation of gas in the main burner.

Cold Test: The temperature in degrees Fahrenheit at which a lubricant passes from the fluid to the solid state.

Combustion Chamber: That part of an explosive motor in which the gases are compressed and then fired, usually by an electric spark.

Combustion Space: See "Clearance" and "Clearance Space".

Commercial Car: A motor-driven vehicle for commercial use, such as transporting passengers or freight.

Commutator: In the ignition system of an explosive motor, the commutator is a device to automatically complete the circuit of each of a number of cylinders in succession.

Commutator of Dynamo or Motor: That part of a dynamo which is designed to cause the alternating current produced in the armature to flow in one direction in the external circuit; in a motor, to change the direct current in the external circuit into alternating current.

Compensating Carbureter: An automatic attachment to a carbureter controlling either air or fuel admission, or both, so that the proportion of one to the other is always maintained under any vibration of power required.

Compensating Gear: See "Differential Gear".

Compensating Joint: See "Universal Joint".

Compound Engine: A multiple-expansion steam engine in which the steam is expanded in two stages, first in the high-pressure cylinder and then in the low-pressure cylinder.

Compression: (1) That part of the cycle of a gas engine in which the charge is compressed before ignition; in a steam engine it is the phase of the cycle in which the pressure is increased, due to compression of the exhaust steam behind the piston. (2) The greatest pressure exerted on the gas in the compression chamber.

Compression Chamber: The clearance volume above the piston in a gas engine; also called "Compression Space".

Compression Cock: See "Compression-Relief Cock".

Compression Line: The line on an indicator diagram corresponding to the phase of the cycle in which the gas is compressed.

Compression-Relief Cock: A small cock by which the compression chamber of an internal-combustion motor may be opened to the air and thus allow the compression in the cylinder to be relieved to facilitate turning by hand, or *cranking*.

Compression Space: See "Compression Chamber".

Compression Tester: A small pressure gage by which the degree of compression of the mixture in a gas-engine cylinder may be tested.

Compressor, Air: See "Air Compressor".

Condenser: (1) In a steam motor, an apparatus in which the exhaust steam is converted back into water. (2) A device for increasing the electric capacity of a circuit. Used in an ignition circuit to increase the strength of the spark.

Cone Bearing: A shaft bearing in which the shaft is turned to a taper and the journal turned to a conical or taper form.

Cone Clutch: A friction clutch in which there are two cones, one fitting within the other.

Connecting Rods: The part of an engine connecting the piston to the crank, and by means of which a reciprocating motion of the piston is converted into the rotary motion of the crank.

Constricting Band Brake: See "Brake, Constricting Band".

Constricting Clutch: A friction clutch in which a band is tightened around a drum to engage it.

Contact Breaker: A device on some forms of gasoline motors having an induction coil of the single jump-spark type, to open and close the electric circuit of the battery and coil at the proper time for the passage of the arc or spark at the points of the spark plug.

Contact Maker: See "Contact Breaker".

Continental Drive: Double-chain drive.

Control: The levers, pedals, etc., in general with the speed and direction of a car is regulated by the driver. In speaking of right, left, or center control, the gearshift and emergency brake levers only are meant.

Control, Spark: Method of controlling the power of an engine by varying the point in the stroke at which ignition takes place.

Control, Throttle: Method of governing the power of the engine by altering the area of the passage leading to the admission valve so that the amount of the fuel introduced into the cylinder is varied.

Controller, Electric: Apparatus for securing various combinations of storage cells and of motors so as to vary the speed of the car at will.

Converter: A device for changing alternating current into direct current for charging storage batteries, etc. Converters may be any of three kinds: rotary, electrolytic, or mercury-vapor. The mercury-vapor converter is most widely used.

Convertible Body: An automobile body which may be used in two or more ways, usually as an open or closed carriage, or in which several seats may be concealed, and raised to increase the seating capacity.

Cooling Fan: Fan used in automobiles to increase the current of air circulating around the cylinders, or through the radiator.

Cooling System: The parts of a gas engine or motor car by which the heat is generated in the cylinder by the combustion of the fuel mixture. See "Water Cooling" and "Air Cooling".

Cork Inserts: Pieces of cork inserted in friction surfaces of clutches or brakes to give softer action.

Cotter Pin: A split metal pin designed to pass through holes in a bolt and nut to hold the former in place.

Coulomb: The unit of measure of electrical quantity. Sometimes called "Ampere Second". It is equivalent to the product of the current in amperes by the number of seconds current has been flowing.

Counterbalance: Weights attached to a moving part to balance that part.

Countershaft: An intermediate or secondary shaft in the power-transmission system.

Coupé: An enclosed body seating one or two passengers and the driver, all within.

Coupling, Flexible: See "Universal Joint".

Cowl: That portion of the body of the car which forms a hood over the instrument board or dash.

Cowl Tank: A fuel tank carried under the cowl and immediately in front of the dash.

Crank: A lever designed to convert reciprocating motion into rotating motion or *vice versa;* usually in the form of a lever formed at an angle with the shaft, and connected with piston by means of connecting rod.

Crank, Starting: A handle made to fit the projecting end of the crankshaft of a gas engine, so that the engine may be started revolving by hand.

Crankcase: The casing surrounding the crank end of the engine.

Crankcase Explosion: Explosion of unburned gases in the crankcase.

Crank Chamber: The enclosed space of small engines in which the crank works.

Cranking: The act of rotating the motor by means of a handle in order to start it. Turning the flywheel over a few times causes the engine to take up its cycle, and after an explosion it continues to operate.

Crankpin: The pin by which the connecting rod is attached to the crank.

Crankshaft: The main shaft of an engine.

Crankshaft, Offset: A crankshaft whose center line is not in the same plane as the axis of its cylinders.

Creeping of Pneumatic Tires: The tendency of pneumatic tires to push forward from the ground, and thus around the rim, in the effort to relieve and distribute the pressure.

Cross Member: A structural member of the frame uniting the side members.

Crypto Gear: See "Planetary Gear".

Crystallization. The rearrangement of the molecules of metal into a crystalline form under continued shocks. This is often the cause of the breaking of the axles and springs of a motor car.

Cup, Priming: A small cup-shaped device provided with a cock, by which a small quantity of gasoline can be introduced into the cylinder of a gasoline engine.

Current: The rate of flow of electricity; the quantity of electricity which passes per second through a conductor or circuit.

Current Breaker: See "Contact Breaker".

Current Indicator: A device to indicate the direction of current flow in a circuit; a polarity indicator.

Current Rectifier: A device for converting alternating current into direct current. See "Converter".

Cushion Tire: See "Tire, Cushion".

Cut-Off, Gas Engine: That point in the cycle of an internal-combustion engine at which the admission of the mixture is discontinued by the closing of the admission valve.

Cut-Off, Steam Engine: That point in the cyle of a steam engine, or that point on an indicator diagram, at which the admission of steam is discontinued by the closing of the admission valve.

Cut-Out, Automatic: A device in a battery charging circuit designed to disconnect the battery from the circuit when the current is not of the proper voltage.

Cut-Out, Muffler: A device by which the engine is made to exhaust into the air instead of into the muffler.

Cut-Out Pedal: Pedal by means of which the engine is made to exhaust into the air instead of into the muffler.

Cycle: A complete series of operations beginning with the drawing in of the working gas, and ending after the discharge of the spent gas.

Cycle, Beau de Rochas: See "Beau de Rochas Cycle".

Cylinder: A part of a reciprocating engine consisting of a cylindrical chamber in which a gas is allowed to expand and move a piston connected to a crank.

Cylinder Bore: See "Bore".

Cylinder Cock: A small cock used to allow the condensed water to be drained away from the cylinder of a steam engine, usually called a *drain cock.*

Cylinder Head: That portion of a cylinder which closes one end.

Cylinder Jacket: See "Jacket, Water".

Cylinder Oil: Lubricant particularly adapted to the lubrication of cylinder walls and pistons of engines.

D

Dash: The upright partition of a car in front of the front seat and just behind the bonnet.

Dash Adjustment: Connections by which a motor auxiliary may be adjusted by a handle on the dash. Usually applied to carbureter adjustments.

Dash Coil: An induction coil for jump-spark ignition, having an element for each cylinder, with dash connections to the commutator on the engine or camshaft.

Dash Gage: A steam, water, oil, or electric gage placed upon the dash of the car.

Day Type of Engine: The two-cycle internal-combustion engine with an air-tight crankcase.

Dead Axle: See "Axle, Dead".

Dead Center: The position of the crank and connecting rod in which they are in the same straight line. There are two positions, and in these positions no rotation of the crankshaft is caused by pressure on the piston.

Decarbonizer: See "Carbon Remover".

Deflate: Reduction of pressure of air in a pneumatic tire.

Deflector: In a two-cycle engine, the curved plate on the piston head designed to cause the incoming charge to force out the exhaust gases and thus assist in scavenging.

Deflocculated Graphite: Graphite so finely divided that it remains in suspension in a liquid.

Demountable Rim: A rim upon which a spare tire may be mounted and carried, and so arranged that it may be easily and quickly taken off or put on the wheel.

Denatured Alcohol: See "Alcohol, Denatured".

Densimeter: See "Hydrometer".

Depolarizer: Material surrounding the negative element of a primary cell to absorb the gas which would otherwise cause polarizing.

Detachable Body: A body which may be detached from and placed upon the chassis.

Detachable Rim: See "Demountable Rim".

Diagram Indicator: See "Indicator Card".

Diagram, Jeantaud: A diagrammatic representation of the running gear of an automobile, showing it turning corners of various radii for the purpose of determining the front-axle and steering connections.

Diesel Gas Engine: Four-cycle internal-combustion engine in which the explosion of the charge is accomplished entirely by the temperature produced by the high compression of the mixture.

Differential, Bevel-Gear: A balance gear in which the equalizing action is obtained by means of bevel gears.

Differential, Spur-Gear: A differential gear in which the equalizing action is obtained by spur gears.

Differential Brake: See "Brake, Differential".

Differential Case: See "Differential Housing".

Differential Gear: A mechanism to permit driving the wheels and yet allow them to turn a corner without slipping. An arrangement such that the driving wheels may turn independently of each other on a divided axle, both wheels being under the control of the driving mechanism. Sometimes called *balance, compensating,* or *equalizing gear.*

Differential Housing: The case that encloses the differential gear.

Differential Lock: A device which prevents the operation of the differential gear, so that the wheels turn as if they were on a solid shaft.

Dimmer: An arrangement for lowering the intensity of, or reducing the glare from headlights.

Direct Current: A current which does not change its direction of flow, as the current from a battery or a direct-current generator Distinguished from an alternating current, which reverses its direction many times a minute.

Direct Drive: Transmission of power from engine to the final driving mechanism at crankshaft speed.

Discharge: In a storage battery, the passage of a current of electricity stored therein. In the ignition circuit, the flow of high-tension current at the spark gap.

Disk Clutch: A clutch in which the power is transmitted by a number of thin plates pressed face to face.

Distance Rod: See "Radius Rod".

Distribution Shaft: See "Camshaft".

Distributor: That part of the ignition system which directs the high-tension current, to the respective spark plugs in the proper firing order.

Double Ignition: A method of ignition which comprises two separate systems, either of which may be used independently of the other, or both together as desired. Usually distinguished by two current sources and two sets of plugs.

Drag: That action of a clutch or brake which does not completely release.

Drag Link: That rod in a steering gear which forms the connection between the mechanism mounted on the frame and the axle stub, and transmits the movements of steering from steering post to wheels.

Drive Shaft: The shaft transmitting the motion from the change gears to the driving axle; the torsion rod.

Driving Axle: The axle of a motor car through which the power is transmitted to the wheels.

Driving Wheel: The wheel to which or by which the motion is transmitted.

Dry Battery: A battery of one or more dry cells.

Dry Cell: A primary voltaic cell in which a moist material is used in place of the ordinary fluid electrolyte.

Dual Ignition: An ignition system comprising two sources of current and one set of spark plugs.

Dust Cap: A metal cap to be screwed over a tire valve to protect the latter from dust and water.

Dynamo: The name frequently applied to a dynamo-electric machine used as a generator. Strictly, the term *dynamo* should be applied to both motor and generator.

Dynamometer: The form of equalizing gear attached to a source of power or a piece of machinery to ascertain the power necessary to operate the machinery at a given rate of speed and under a given load.

E

Earth: See "Ground".

Economizer, Gas: An appliance to be attached to a float-feed carbureter to improve the mixture by automatically governing the amount of air in the float chamber.

Eccentric: A disk mounted off-center on a shaft to convert rotary into reciprocating motion.

Economy, Fuel: The fuel economy of a motor is the relation between the heat units in the fuel used in the motor and the work or energy given out by the motor.

Efficiency: The proportion of power obtained from a mechanism as compared with that put into it.

Efficiency of a Motor: The efficiency of a gasoline motor is the relation between the heat units consumed by the motor and the work of energy in foot-pounds given out by it. Electrical efficiency of a motor is the relation between the electrical energy put into the motor and the mechanical energy given out by it.

Ejector: An apparatus by which a jet of steam propels a stream of water in almost the same way as an injector, except that the ejector delivers it into a vessel having but little pressure in it.

Electric Generator: A dynamo-electric machine in which mechanical energy is transformed into electrical energy; usually called *dynamo.*

Electric Horn: An automobile horn electrically operated.

Electric Motor: A dynamo-electric machine in which electrical energy is transformed into mechanical energy.

Electric Vehicle: An automobile propelled by an electric motor, for which current is supplied by a storage battery carried in the vehicle.

Electrolyte: A compound which can be decomposed by electric current. In referring to storage batteries, the term electrolyte means the solution of sulphuric acid in water in which the positive and negative plates are immersed.

Electromagnet: A temporary magnet which obtains its magnetic properties by the action of an electric current around it and which is a magnet only as long as such current is flowing.

Electromotive Force: A tendency to cause a current of electricity to flow; usually synonymous with *potential, difference of potential, voltage*, etc.

Element: The dissimilar substances in a battery between which an electromotive force is set up, as the plates of a storage battery.

Emergency Brake: A brake to be applied when a quick stop is necessary; usually operated by a pedal or lever.

En Bloc: That method of casting the cylinders of a gasoline engine in which all the cylinders are made as a single casting. Block casting; monoblock casting.

End Play: Motion of a shaft along its axis.

Engine, Alcohol: An internal-combustion engine in which a mixture of alcohol and air is used as fuel.

Engine, Gasoline: An internal-combustion motor in which a mixture of gasoline and air is used as fuel.

Engine, Kerosene: An internal-combustion engine in which a mixture of kerosene and air is used as fuel.

Engine, Steam: An engine in which the energy in steam is used to do work by moving the piston in a cylinder.

Engine Primer: A small pump to force fuel into the carbureter.

Engine Starter: An apparatus by which a gasoline engine may be started in its cycle of operations without use of the starting crank. It belongs usually to one of four classes: (1) Mechanical or spring actuated, such as a coil spring wound up by the running of the engine or a strap around the flywheel; (2) fluid pressure, such as compressed air or exhaust gases induced into the cylinder to drive the piston through one cycle; (3) the electric system, in which a small motor is used to turn the engine over; (4) combinations of these.

Epicyclic Gear: See "Planetary Gear".

Equalizing Gear: See "Differential Gear".

Exhaust: The gases emitted from a cylinder after they have expanded and given up their energy to the piston; the emission of the exhaust gases.

Exhaust, Auxiliary: See "Auxiliary Exhaust".

Exhaust Horn: An automobile horn in which the sound is produced by the exhaust gases.

Exhaust Lap: The extension of the inside edges of a slide valve to give earlier closing of the exhaust. Also called *inside lap.*

Exhaust Manifold: A large pipe into which the exhaust passages from all the cylinders open.

Exhaust Port: The opening through which the exhaust gases are permitted to escape from the cylinder.

Exhaust Steam: Steam which has given up its energy in the cylinder and is allowed to escape.

Exhaust Stroke: The stroke of an internal-combustion motor during which the burned gases are expelled from the cylinder.

Exhaust Valve: A valve in the cylinder of an engine through which the exhaust gases are expelled.

Expanding Clutch: A clutch in which a split pulley is expanded to press on the inner circumference of a ring which surrounds it, and thus transmits motion to the ring.

Expansion, Gas Engine: That part of the cycle of a gas engine immediately after ignition, in which the gas expands and drives the piston forward.

Expansion, Steam Engine: That portion of the stroke of the steam engine in which the steam is cut off by the valves and continues to perform work on the piston, increasing in volume and decreasing in pressure.

Explosive Motor: See "Internal-Combustion Motor".

F

Fan, Cooling: A mechanically operated fan for producing a current of air for cooling the radiator or cylinder of a gas engine.

Fan, Radiator: A mechanically operated rotary fan used to induce the flow of air through the radiator to facilitate the cooling of the water.

Fan Belt: The belt which drives the cooling fan.

Fan Pulley: A pulley permanently attached to the fan and over which the fan belt runs to drive it.

Fat Spark: A short, thick, ignition spark.

Feed Pump: A pump by which water is delivered from the tank to the boiler of a steam car.

Feed Regulator: A device to maintain a uniform water level in a steam boiler by controlling the speed of the feed pump.

Feed-Water Heater: An apparatus for heating the boiler-feed water, either by means of a jet of steam or steam-heated coils.

Fender: A mud guard or shield over the wheels of a car.

Field, Magnetic: Space in the neighborhood of the poles of a magnet in which the magnetism exerts influence. Field also refers to the coils which produce the magnetism in an electromagnet.

Fierce Clutch: A clutch which cannot be engaged easily. A grabbing clutch.

Filler Board: Woodwork shaped to fill the space between the lower edge of the windshield and the dash.

Fin: Projections cast on the cylinders of a gas engine to assist in cooling.

Final Drive: That part of a car by which the driving effort is transmitted from the parts of the transmission carried on the frame to the transmission parts on the rear axle. The propeller shaft in a shaft-drive car.

Fire Test: A test of a lubricant to determine the temperature at which it will burn.

Firing: (1) Ignition of the charge in a gas engine. (2) The act of furnishing fuel under the boiler of a steam engine.

First Speed: That combination of transmission gears which gives the lowest gear ration forward. Slow speed; low speed.

Flash Boiler: A boiler arranged to generate highly superheated steam almost instantaneously, by allowing water to come in contact with very hot metal surfaces.

Flash Generator: See "Flash Boiler".

Flash Point: The temperature at which an oil will give off a vapor that will ignite when a flame comes in contact with it.

Flash Test: A test to determine the flash point of oils.

Flexibility: In an engine the ability to do useful work through a range of speeds.

Flexible Coupling: See "Universal Joint".

Flexible Shaft: A pliant shaft which will transmit considerable power when revolving.

Flexible Tubing: A tube for the conduction of liquids or gases, which may be bent at a small radius without leaking.

Float Carbureter: A carbureter for gasoline engines in which a float of cork or hollow metal controls the height of the liquid in the atomizing nozzle. Sometimes called *float-feed carbureter*.

Float Valve: An automatic valve by which the admission of a liquid into a tank is controlled through a lever attached to a hollow sphere which floats on the surface of the liquid and opens or closes the valve according as it is high or low.

Floating Axle: See "Axle, Floating".

Floating the Battery on the Line: Charging the battery while it is giving out current.

Flooding: Excessive escape of fuel in a carbureter from the spraying nozzle.

Flushing Pin: In a float-feed carbureter, a pin arranged to depress the float in priming. Also called *primer* and *tickler*.

Flywheel: A wheel upon the shaft of an engine which, by virtue of its moving mass, stores up the energy of the gas transmitted to the flywheel during the impulse stroke and delivers it during the rest of the cycle, thus producing a fairly constant torque.

Flywheel Marking: Marks on the face of a flywheel to indicate the time of valve opening and closing and thus assist in valve setting.

Foaming: See "Priming".

Fore Carriage: A self-propelled vehicle in which the motor is carried on the forward trucks, and propelling and steering is done with the forward trucks.

Fore-Door Body: An automobile body having doors in the forward compartment.

Four-Cycle or Four-Stroke Cycle: The cycle of operations in gas engines occupying two complete revolutions or four strokes.

Four-Wheel Drive: Transmission of driving effort to all four wheels.

Fourth Speed: That combination of transmission gears which gives the fourth from the lowest gear ratio forward. Usually the highest speed.

Frame: The main structural part of a chassis. It is carried upon the axles by the springs and carries the different elements of the car.

Frame Hangers: See "Body Hangers".

Free Wheel: A wheel so arranged that it can rotate more rapidly than the mechanism which drives it.

Friction: The resistance existing between two bodies in contact which tends to prevent their motion on each other.

Friction Clutch: A device for coupling and disengaging two pieces of shafting while in motion, by the friction of cones or plates on one another.

Friction Disk: The thin plate used in a disk or friction clutch. See "Disk Clutch".

Friction Drive: A method of transmitting power or motion by frictional contact.

Fuel: A combustible substance by whose combustion power is produced. Gasoline and kerosene are the chief automobile fuels.

Fuel Economy. See "Economy, Fuel".

Fuel Feed, Gravity: See "Gravity Fuel Feed".

Fuel Feed, Pressure: See "Lubrication, Force-Feed."

Fuel Feed, Vacuum. See "Vacuum Fuel Feed".

Fuel-Feed Regulator: A device in the fuel system of steam motor by which the rate of flow of fuel to the burner is automatically regulated.

Fuel Level: The height of the top of the fuel in the float chamber of a carbureter.

Fuel-Level Indicator: An instrument either permanently connected to the fuel tank or which may be inserted thereon to indicate the quantity of fuel in the tank.

Fuel Tank, Auxiliary: A tank designed to hold a supply of fuel in addition to that carried in the main shaft.

Fuse: A length of wire in an electric circuit designed to melt and open the circuit when excess current flows through it and thus prevent damage to other portions of the circuit.

Fusible Plug: A hollow plug filled with an alloy which melts at a point slightly above the temperature of the steam in a boiler, as when the water runs low, thus putting out the fire and preventing the burning out of the boiler.

G

Gage: (1) Strictly speaking, a measure of, or instrument for determining dimensions or capacity. Practically, the term refers to an instrument for indicating the pressure or level of liquids, etc. (2) The distance between the forward or rear wheels measured at the points of contact of the tires on the road. Tread; track.

Gage Cock: A small cock by which a pipe leading to a gage may be opened or closed.

Gage Lamp: Lamp, usually electric, placed above or near the gages to enable them to be read at night.

Gage, Oil: See "Oil Gage".

Gage, Tire: See "Tire-Pressure Gage".

Gap: In automobiles, the spark gap.

Garage: A building for storing and caring for automobiles.

Garage, Portable: A garage which may be moved from one place to another either as a whole or in sections.

Gas: Matter in a fluid form which is elastic and has a tendency to expand indefinitely with reduction in pressure.

Gas Economizer: See "Economizer".

Gas Engine: An internal-combustion motor in which a mixture of gas and air is used as fuel. The term is also applied to the gasoline engine.

Gas Engine, Otto: A four-stroke cycle engine developed by Otto and using the hot-tube method of ignition.

Gas Generator: An apparatus in which a gas is generated for any use.

Gas Lamp: See "Acetylene Lamp".

Gases, Boyle's Law of: See "Boyle's Law of Gases".

Gases, Gay Lussac's Law of: Called *Charles's Law* and the *Second Law of Gases.* Law defining the physical properties of gases at constantly maintained pressure. It states that at constant pressure the volume of gas varies with the temperature, the increase being in proportion to the change of temperature and volume of the gas.

Gasket: A thin sheet of packing material or metal used in making joints, piping, etc.

Gasoline: A highly volatile fluid petroleum distillate; a mixture of fluid hydrocarbons.

Gasoline-Electric Transmission: A system of propulsion in which a gasoline engine drives an electric generator, and the power is transmitted electrically to motors which drive the wheels.

Gasoline Engine: An internal-combustion motor in which a mixture of gasoline and air is used as a fuel.

Gasoline Primer: The valve on the carbureter of a gasoline engine by which the action of the engine can be started.

Gasoline-Tank Gage: A fuel-lever indicator for gasoline.

Gasoline Tester: A hydrometer graduated to indicate the specific gravity of gasoline, usually in degrees Baumé.

Gate: A plate which guides the gearshift lever in making speed changes.

Gather: Convergence of the forward portions of the front wheels. Toeing in.

Gay Lussac's Law of Gases: See "Gases, Gay Lussac's Law of".

Gear, Balance: See "Differential Gear".

Gear, Bevel: See "Bevel Gear".

Gear, Change-Speed: An arrangement of gear wheels which transmits the power of the motor to the differential gear at variable speeds independently of the motor speed.

Gear, Differential: See "Differential".

Gear, Fiber: A gear cut from a vulcanized fiber blank.

Gear, Helical: A gear whose teeth are not parallel to the axis of the cylinders.

Gear, Internal: A gear whose teeth project inward toward the center from the circumference of gear wheel.

Gear, Planetary: See "Planetary Gears".

Gear, Progressive: See "Progressive Change-Speed Gears".

Gear, Rawhide: A gear cut from a blank made up of compressed rawhide.

Gear, Selective: See "Selective Change-Speed Gears".

Gear, Timing: See "Timing Gears".

Gear, Worm: A helical gear designed for transmitting motion at angles, usually at right angles and with a comparatively great speed reduction.

Gearbox: The case covering the change-speed gears.

Gear Shifting: Varying the speed ration between motor and rear wheels by operating the change-speed gears.

Gear-Shift Lever: A lever by which the change-speed gears are shifted.

Geared-Up Speed: A speed obtained by an arrangement of gears in the gearset such that the propeller shaft rotates more rapidly than the crankshaft.

Gearset: See "Gear, Change-Speed".

Generator, Acetylene: See "Acetylene Generator".

Generator, Electric: See "Electric Generator".

Generator, Steam: A steam boiler.

Generator Tubing: Tubing by which acetylene is conducted from the generator to the lamp.

Gimbal Joint: A form of universal joint.

Gong: A loud, clear sounding bell, usually operated either electrically or by foot power.

Governor: A device for automatically regulating the speed of an engine.

Governor, Dynamo: A method of automatic control of the generator (usually an ignition generator, in automobile work) by which its speed is maintained approximately constant.

Governor, Hydraulic: A governor applied to engines cooled by a pump circulation of water in such a way that the throttle opening is controlled by the pressure of the water.

Governor, Spark: A method of automatically controlling the speed of the engine by varying the time of ignition. See "Governor".

Grabbing Clutch: See "Fierce Clutch".

Gradometer: An instrument for indicating the degree of the gradient or the per cent of the grade. It consists of a level with a graduated scale.

Graphite: One of the forms in which carbon occurs in matter. Also known as *black lead* and *plumbago*. Used as a lubricant in powdered or flake form in the cylinders of explosive engines.

Gravity-Feed Oiling System: See "Lubrication, Gravity".

Gravity Fuel Feed: Supply of fuel to the carbureter from the tank by force of gravity.

Grease and Oil Gun: A syringe by means of which grease or oil may be introduced into the bearings of the machinery.

Grease Cup: A device designed to feed grease to a bearing by the compression of a hand screw.

Grid: A lead plate formed in the shape of a gridiron to sustain and act as a conductor of electricity for the active material in a storage battery.

Grinding Valves: See "Valve Grinding".

Gripping Clutch: See "Fierce Clutch".

Ground: An electric connection with the earth, or to the framework of a machine.

H

Half-Motion Shaft: See "Half-Time Shaft".

Half-Time Gear: See "Timing Gears".

Half-Time Shaft: The cam shaft of a four-cycle gas engine. It revolves at one-half the speed of the crankshaft.

Hammer Break: A make-and-break ignition system in which the spark is produced when the moving terminal strikes the stationary terminal like a hammer.

Header: A pipe from which two or more pipes branch. Manifold.

Heater, Automobile: A device for warming the interior of an automobile, usually electric, or by means of exhaust gases or jacket water.

High Gear: That combination of change-speed gears which gives the highest speed.

High-Tension Current: A current of high voltage, as the current induced in the secondary circuit of a spark coil.

High-Tension Ignition: Ignition by means of high-tension current.

High-Tension Magneto: A magneto which delivers high-tension current.

Honeycomb Radiator: A radiator consisting of many very thin tubes, giving it a cellular appearance.

Hood: (1) That part of the automobile body which covers the frame in front of the dash. The engine is usually under the hood. (2) The removable covering for the motor.

Hooke's Coupler: See "Universal Joint".

Horizontal Motor: A motor the center line of whose cylinder lies in a horizontal plane.

Horn, Automobile: A whistle or horn for giving warning of the approach of the automobile.

Horsepower: The rate of work or energy expended in a given time by a motor. One horsepower is the rate or energy expended in raising a weight of 550 pounds one foot in one second, or raising 33,000 pounds one foot in one minute.

Horsepower Brake: The power delivered at the flywheel of an internal combustion engine as ascertained by a brake test.

Horsepower, Rated: The calculated power which may be expected to be delivered by a motor. In America the term usually refers to the horsepower as calculated by the S.A.E. formula.

Hot-Air Intake: The pipe or opening conveying heated air to the carbureter.

Hot-Head Ignition: The method of igniting the charge in a gas-engine cylinder by maintaining the head of the combustion chamber at a high temperature from the internal heat of combustion, as in the Diesel engine.

Hot-Tube Ignition: An ignition device formerly used for gas engines in which a closed metal tube is heated red-hot by a Bunsen flame. When the compressed gases in the cylinder are allowed to come in contact with this, ignition takes place.

Housing: A metallic covering for moving parts.

H.P.: (1) Abbreviation for *horsepower*. (2) Abbreviation for *high pressure*.

Hub Cap: A metal cap placed over the outer end of a wheel hub.

Hydrocarbons: Chemical combinations of carbon and hydrogen in varied proportions, usually distillates of petroleum, such as gasoline, kerosene, etc.

Hydrometer: An instrument by which the specific gravity or density of liquids may be ascertained.

Hydrometer Scale, Baumè's: An arbitrary measure of specific gravity.

I

I-Beam: Sometimes called *I-Section*. A structural piece having a cross section resembling the letter I. I-Beam front axle.

Igniter: An insulated contact plug without sparking points, used in make-and-break ignition with low-tension magneto.

Igniter, High-Speed: An igniter having a short spark coil for high-speed engines.

Igniter, Jump-Spark: A system of ignition in which is used a current of high pressure, which will jump across a gap in the high-pressure circuit, causing a spark at the gap.

Igniter, Lead of: Amount by which the ignition is advanced. See "Advanced Ignition".

Igniter, Primary: The apparatus in a primary circuit for making and breaking the circuit.

Igniter Spring: A spring to quickly break the circuit of a primary igniter.

Ignition, Advancing: See "Advanced Ignition".

Ignition, Battery: A system which gets its supply of current from a storage battery or dry cells. This system usually consists of a battery, a step-up coil, and a distributor for sending the current to the different spark plugs.

Ignition, Catalytic: Method of ignition for explosive motors based on the property of some metals, particularly spongy platinum, of becoming incandescent when in contact with coal gas or carbonized air.

Ignition, Double: See "Double Ignition".

Ignition, Dual: See "Dual Ignition".

Ignition, Fixed: Ignition in which the spark occurs at a given point in the cycle and cannot be changed from that point at the will of the operator except by retiming the ignition system. Fixed spark.

Ignition, Generator: Ignition current which is furnished by a combination lighting generator and magneto. The generator is fitted with an interrupter and distributor. Sometimes refers to system in which a generator charges a battery and the latter furnishes the ignition current in connection with a coil and distributor.

Ignition, High-Tension: Sometimes called jump-spark. Ignition which is effected by means of a high-tension or high-voltage current which is necessary to jump a gap in the spark plug.

Ignition, Hot-Head: See "Hot-Head Ignition".

Ignition, Jump-Spark: See "Ignition, High-Tension".

Ignition, Low-Tension: See "Ignition, Make-and-Break".

Ignition, Make-and-Break: A system in which the spark is produced by the breaking or interruption of a circuit, the break occurring in the combustion space of the cylinder. The current used is of low-voltage, hence the synonym, low-tension ignition.

Ignition, Magneto: Ignition produced by an electric generator, called a magneto, which is operated by the gas engine for which it furnishes current. Dynamo ignition. Generator ignition.

Ignition, Master Vibrator: A system which uses as many non-vibrator coils as there are cylinders, and one additional coil, called the master vibrator, for interrupting the primary circuit for all coils. The master vibrator also is used with vibrator coils in which the vibrators are short-circuited.

Ignition, Premature: Ignition occurring so far before the top dead center mark that the explosion occurs before the piston has reached upper dead center.

Ignition, Primary: An ignition system in which a low-tension current flows through a primary coil, the circuit being mechanically opened, allowing a high-tension spark to jump across the gap. See "Primary Coil".

Ignition, Retarding: Setting the spark of an internal-combustion motor so that the ignition will occur at a later part of the stroke.

Ignition, Self: Explosion of the combustible charge by heat other than that produced by the spark. Incandescent carbon will cause this. Motor overheating because of lack of water is another cause.

Ignition, Single: A system using but one source of current.

Ignition, Synchronized: Ignition by means of which the timing in each cylinder of a multicylinder engine is the same. In synchronized ignition the spark occurs at the same point in the cycle in each cylinder. This type of ignition is obtained with a magneto and is lacking in a multi-coil system using vibrator coils.

Ignition, Timing of: The adjustment of the ignition system so that ignition will take place at the desired part of the cycle.

Ignition, Two-Independent: See "Ignition, Double".

Ignition, Two-Point: A system comprising two ignition sources, or a double-distributor magneto, and two sets of spark plugs, both of which spark at the same time.

Ignition Distributor: See "Distributor."

Ignition Switch: A control or switch for turning the ignition current on and off voluntarily.

I. H. P.: Abbreviation for *indicated horsepower*.

Indicated Horsepower: (1) The horsepower developed by the fuel on the pistons, in contradistinction to brake horsepower. See "Horsepower, Brake". (2) The horsepower of an engine as ascertained from an indicator diagram.

Indicator: An instrument by which the working gas in an engine records its working pressure.

Indicator Card: A figure drawn by means of an indicator by the working gas in an engine. Also called *indicator diagram.*

Induction Stroke: The downstroke of a piston which causes a charge of mixture to be drawn into the cylinder.

Inflammation: The act or period of combustion of the mixture in the cylinder.

Inflate: To increase the pressure within a tire by forcing air into it.

Inflator, Mechanical Tire: A small power-driven air-pump for inflating the tire; either driven by gearing, chain, or belt from the engine shaft, or by friction from the flywheel.

Inherent Regulation: Expression applied to electric generators which use no outside means of regulating the output, the regulation being affected by various windings of the armature and fields.

Initial Air Inlet: See "Primary Air Inlet".

Initial Pressure: Pressure in a cylinder after the charge has been drawn in but not compressed.

Injector: A boiler-feeding device in which the momentum of a steam jet, directed by a series of conical nozzles, carries a stream of water into the boiler, the steam condensing within and heating the water which it forces along.

Inlet, Valve: The valve which controls the inlet port and so allows or prevents mixture from passing to the cylinder.

Inlet Port: Passage or entrance in the cylinder wall through which the fuel mixture is taken. Sometimes called intake port.

Inlet Manifold: Sometimes called intake manifold or header. A branched pipe connected to the mixing chamber at one end and at the branch ends to the cylinders so as to communicate with the inlet ports.

Inlet Manifold, Integral: A manifold or header cast integral with the cylinder.

Inner-Tire Shoe: A piece of leather or rubber placed within the tire to protect the inner tube.

Inner Tube: A soft air-tight tube of nearly pure rubber, which fits within a felloe upon the casing.

Inside Lap: See "Exhaust Lap".

Intake Manifold: The large pipe which supplies the smaller intake pipes from each cylinder of a gas engine.

Intake Pipe: Sometimes made synonymous with inlet manifold. Correctly, the pipe from the carbureter to the inlet manifold.

Intake Stroke: See "Induction Stroke".

Intensifier: See "Outside Spark Gap".

Intermediate Gear: A gear in a change-speed set between high and low. In a three-speed set it would be second speed. In a four, either second or third.

Intermediate Shaft: See "Shaft, Intermediate".

Internal-Combustion Motor: Any prime mover in which the energy is obtained by the combustion of the fuel within the cylinder.

Internal Gear: See "Gear, Internal".

Interrupter: See "Vibrator".

J

Jack: A mechanism by which a small force exerted over a comparatively large distance is enabled to raise a heavy body. Used for raising the automobile axle to remove the weight from the wheels.

Jacket, Water: A portion of the cylinder casting through which water flows to cool the cylinder.

Jacket Water: The cooling water circulating in a water-cooling system.

Jackshaft: Shaft used in double-chain drive vehicles. Shaft placed transversally in the frame and driving from its ends chains which turn the rear wheels mounted on a dead axle.

Jeantaud Diagram: See "Diagram, Jeantaud".

Joint Knuckle: See "Swivel Joint."

Joule's Law of Gases: See "Gases, Joule's Law of".

Jump Spark: A spark produced by a secondary jump-spark coil.

Jump Spark, Circuit Maker: A mechanically operated switch by which the circuit in a jump-spark ignition system is opened and closed.

Jump-Spark Coil: An electrical transformer and interrupter, consisting of a primary winding of a few turns of coarse wire surrounding an iron core, and a secondary winding consisting of a great number of turns of very fine wire. The condenser is usually combined with this. Also known as *secondary spark coil.*

Jump-Spark Igniter: See "Igniter, Jump-Spark".

Jump-Spark Plug: See "Spark Plug".

Junction Box: A portion of an electric-lighting system to which all wires are carried for the making of proper connections.

Junk Ring: A packing ring used in sleeve-valve motors. It has the same functions as a piston ring. See "Piston Ring".

K

Kerosene: A petroleum product having a specific gravity between 58° and 40° Baumé. It is used as a fuel in internal-combustion engines and can often be used in gasoline engines by starting the engine on gasoline, then switching to kerosene.

Kerosene Burner: A burner especially adapted to use kerosene as a fuel.

Kerosene Engine: An engine using kerosene as fuel.

Key: A semicircular or oblong piece of metal used to hold a member firmly on a revolving shaft so as to prevent the member from rotating.

Key, Baldwin: A key with an oblong section.

Key, Woodruff: A key with a semicircular section.

Keyway: Slot in a rotating member used to hold the key

Kick Switch: Ignition switch mounted so that the driver can operate it with the foot.

Kilowatt: An electrical unit equal to 1000 watts.

Knuckle Joint: See "Swivel Joint".

L

Labor: The jerky operation of an engine. The engine is said to labor when it cannot pull its load without misfiring or jerking.

Lag, Combustion: The time between the instant of the spark occurrence and the explosion.

Lag, Ignition: The time between the instant of spark occurrence and the time at which the spark mechanism producing it begins to act.

Lamp, Trouble: Sometimes called inspection lamp. A small electric bulb carried in a suitable housing, and attached to a long piece of lamp cord. Used for inspecting parts of the car.

Lamp Bulb: The incandescent bulb used in a lamp.

Lamp Bracket: A support for a lamp.

Lamp Lighter: An apparatus for lighting gas lamps by electricity. The lamps are usually so arranged that by pushing the button the gas is turned on and the spark made at the same time.

Landaulet: A type of car which may be used as an open or closed car. The rear portion of the body may be folded down like a top.

Landaulet Body: An automobile body resembling a limousine body, but having a cover fitted to the back, which may be let down, leaving the back open. The top generally extends over the driver.

Lap: To make parts fit perfectly by operating them with an abrasive, such as ground glass, between the rubbing surfaces. To finish.

Lap of Steam Valves: In the slide valve of a steam engine, the amount by which the admission edges overlap the steam port when the valve is central with the cylinder case.

Layshaft: A countershaft or secondary shaft of a gearset operated by the main or shifter shaft.

Lead, or Lead Wire: Any wire carrying electricity.

Lead: In a steam engine the amount by which the steam port is opened when the piston is at the start of its stroke.

Lead Battery: See "Accumulator".

Lead of Igniter: See "Igniter, Lead of".

Lead of Valve: In an engine the amount by which the admission port is opened when the piston is at the beginning of the stroke; according as this is greater or less, the admission of working fluid is varied through several fractions of the stroke.

Lean Mixture: Fuel after leaving the carbureter, which contains too much air in proportion to the gasoline. Sometimes called thin mixture, rare mixture, or weak mixture.

Lever, Brake: See "Brake Lever."

Lever, Change-Speed: Lever by which the different combinations of change gears are made so as to vary the speed of the driving wheels in relation to the speed of the engine; also called gearshift lever.

Lever, Spark: Lever by which the speed and power of the engine are controlled by adjusting the time of ignition.

Lever, Steering: See "Steering Lever".

Lever, Throttle: A lever by which the speed and power of the engine are controlled by adjusting the amount of mixture admitted to the cylinder.

Lever Lock: An arrangement for locking the gearshift lever in free position so that with the engine running the driving axle will not be driven.

Lift: The distance through which a poppet valve is moved in opening from fully-closed to fully-open position.

Lifting Jack: See "Jack".

Lighting Outfit, Electric: An outfit for electrically lighting an automobile. This usually consists of a dynamo, storage battery, and lamps and switchboard, with the necessary wiring and cut-outs.

Limousine Body: An enclosed automobile body having the front and sides with side doors. The top extends over the seat of the driver.

Liner: One or more pieces of metal placed between two parts so they may be adjusted by varying the thickness of the liner. Sometimes called a shim. Also refers to a tool used for lining up parts.

Liner, Laminated: A liner or shim made in a number of parts, the thickness being varied by removing or adding parts.

Lines of Force: See "Field, Magnetic".

Link Motion: In a steam engine, the name for the arrangement of eccentric rods, links, hangers, and rocking shafts by which the relative motion and position of the slide valves are changed at will, providing for varying rates of expansion of the steam and thus varying the speed for either forward or backward motion.

Live Axle: See "Axle, Live".

Lock, Auto Safety: A device arranged so that it is impossible to start the motor car except by the proper combination or key.

Lock Nut: A nut placed on a bolt immediately behind the main nut to keep the main nut from turning.

Lock Switch: A switch in the ignition circuit so arranged that it can not be thrown on except by the use of a key.

Lock Valve: A valve capable of being secured with lock and key.

Long-Stroke: A gas engine whose stroke is considerably greater than its bore.

Lost Motion: Sometimes called play or backlash. Looseness of space between two moving parts.

Louver: A slit or opening in the side of a hood or bonnet of a motor car. Used to allow air from the draft to escape. A ventilator.

Low Gear: The lowest speed gear. First speed in a change-speed set.

Low-Speed Adjustment: A carbureter adjustment which regulates the mixture when the motor is operating slowly, with little throttling opening.

Low-Speed Band: The brake or friction band which controls the low speed of a planetary change-speed set.

Low-Tension Current: A current of low voltage or pressure, such as is generated by dry cells, storage battery, or low-tension magneto.

Low-Tension Ignition: See "Ignition, Make-and-Break".

Low-Tension Magneto: A magneto which initially generates a current of low voltage.

Low-Tension Winding: The winding of a transformer or induction coil through which the primary or low-tension current flows.

Low Test: Gasoline which has a high density, thus giving a low reading on the Baumé scale. Low-grade gasoline.

Low-Water Alarm: An automatic arrangement by which notice is given that the water in the boiler is becoming too low for safety.

Lubricant: An oil or grease used to diminish friction in the working parts of machinery.

Lubrication: To supply to moving parts and their bearings grease, oil, or other lubricant for the purpose of lessening friction.

Lubrication, Circulating: A system in which the same oil is used over and over.

Lubrication, Constant-Level: A system in which the level in the crankcase is kept to a predetermined level by means of a pump.

Lubrication, Force-Feed: Method of lubricating the moving parts of an engine by forcing the oil to the points of application by means of a pump.

Lubrication, Gravity: Method of supplying oil to moving parts of an engine by having a reservoir at a certain height above the highest point to be lubricated and allowing the oil to flow to the points of application by gravity.

Lubrication, Non-Circulating: A system in which the same oil is used but once.

Lubrication, Pressure-Feed: See "Lubrication, Force-Feed".

Lubrication, Sight-Feed: System of lubrication in which the oil pipe to different points of application is led through a glass tube in plain sight; usually at a point on the dashboard.

Lubrication, Splash: Method of lubricating an engine by feeding oil to the crankcase and allowing the lower edge of the connecting rod to splash into it.

Lubricator: A device containing and supplying oil or grease in regular amounts to the working parts of the machine.

Lubricator, Force-Feed: A pump-like device which automatically forces oil to the moving parts.

M

Magnet: A piece of iron or steel which has the characteristic properties of being able to attract other pieces of iron and steel.

Magnet, Horseshoe: A magnet shaped like the letter U.

Magnet, Permanent: A magnet which when once charged retains its magnetism.

Magnetic Field: See "Field, Magnetic".

Magnetic Spark Plug: A spark plug used in a make-and-break system of ignition in which contact is obtained by means of a magnet.

Magneto: See "Ignition, Magneto".

Magneto: See "Magneto-Electric Generator".

Magneto, Double-Distributor: A magneto with two distributors feeding two sets of spark plugs, two in each cylinder and both sparking at once. See "Ignition, Two-Point."

Magneto, High-Tension: A magneto has two armature windings and requires no outside coil for the generation of high-tension current.

Magneto, Induction: A type of magneto in which the armature and fields are stationary and a rotator or spool-shaped piece of metal is used to break the lines of force.

Magneto, Low-Tension: See "Low-Tension Magneto".

Magneto, Rotating Armature: A magneto in which the armature winding revolves.

Magneto Bracket: A shelf or portion of the crankcase web used to support the magneto.

Magneto Coupling: A flexible joint which connects the magneto with a revolving motor shaft.

Magneto Distributor: See "Distributor".

Magneto-Electric Generator: A machine in which there are no field magnet coils, the magnetic field of the machine being due to the action of permanent steel magnets. Usually contracted to *magneto*.

Main Bearing: A bearing used for supporting the crankshaft.

Manifold: A main pipe or chamber into which or from which a number of smaller pipes lead to other chambers. See "Intake Manifold", "Exhaust Manifold", and "Inlet Manifold".

Manometer: A device for indicating either the velocity or the pressure of the water in the coiling system of a gasoline motor.

Master Vibrator: A single vibrator which interrupts the current to each of a set of several spark coils in order.

Mean Effective Pressure: The average pressure exerted upon a piston throughout its stroke.

M. E. P.: Abbreviation for *mean effective pressure.*

Mercury Arc Rectifier: A mercury vapor converter. See "Mercury Vapor Converter".

Mercury Vapor Converter: An apparatus for converting alternating current into direct current by means of a bubble of mercury in a vacuum. The vapor of mercury possesses the property of allowing the flow of current in one direction only. Its principal use is for charging storage batteries.

Mesh: Two gears whose teeth are so positioned that one gear will drive the other are said to be in mesh.

Misfire: Failure of the mixture to ignite in the cylinder; usually due to poor ignition or poor mixtures.

Miss: The failure of a gas engine to explode in one or more cylinders. Sometimes called misfiring.

Mixing Chamber: A pipe or chamber placed between the carbureter and inlet manifold. Sometimes integral with the carbureter or manifold.

Mixing Tube: A tubular carbureter for a gas or gasoline engine.

Mixing Valve: A device through which air and gas are admitted to form an explosive mixture. The carbureter of a gasoline engine combines the mixing valve and vaporizer.

Mixture: The fuel of a gas engine, consisting of sprayed gasoline mixed with air.

Monobloc: Cast *en bloc* or in one piece. Refers usually to cylinders, which are cast two or more at once.

Motocycle: A trade name for a special make of motorcycle.

Motor, Electric: See "Electric Motor".

Motor, Gasoline: See "Gasoline Motor".

Motor, High-Speed: A gas engine whose rotative speed is very high and whose power output goes up with the speed to an unusual degree.

Motor, Horizontal: A gas engine whose cylinder axis lies in a horizontal plane.

Motor, I-head: A gas engine which has cylinders, a section of which resembles the letter I. This type has the valves in the head.

Motor, L-Head: A gas engine in which a section of cylinders resembles the letter L. The valves in this type are all on one side.

Motor, Long-Stroke: See "Long-Stroke Motor".

Motor, Non-Poppet: A gas engine whose valves are not of the poppet type. In this class is the Knight sleeve valve, the rotary valve, and the piston valve.

Motor, Overhead Valve: A motor with cylinders whose valves are in the head.

Motor, Piston Valve: A gas engine using valves which are in the form of pistons.

Motor, Poppet: A gas engine using poppet-type valves. See "Poppet Valve".

Motor, Revolving Cylinder: A motor whose cylinders revolve as a unit.

Motor, Rotary Valve: One in which the valves consist of slots cut out along cylindrical rods which rotate in the cylinder casting.

Motor, Sliding Sleeve: The Knight type motor in which thin sleeves slide up and down in the cylinder, the sleeves having ports which register with the inlet and exhaust manifolds.

Motor, T-Head: A gas engine with the valves on opposite sides of the cylinders, a section of which resembles the letter T.

Motor, V-Type: A motor whose cylinders are set on the crankcase so as to form an angle of 45 to 90 degrees between them.

Motor, Vertical: A motor with the cylinder axis in a vertical plane.

Motorcycle: A bicycle propelled by a gasoline engine.

Mud Guard: Metal or leather strips placed over the wheels to catch the flying mud and to prevent the clothing from coming in contact with the wheels when entering and leaving the car.

Muffler Cut-Out: See "Cut-Out, Muffler".

Muffler Cut-Out Pedal: See "Cut-Out Pedal".

Muffler Exhaust: A vessel containing partitions, usually perforated with small holes and designed to reduce the noise occasioned by the exhaust gases of an engine, by forcing the gases to expand gradually.

Muffler Explosion: Explosion of unburned gases in exhaust passages of the muffler, usually due to poor ignition or poor mixture.

Multiple Circuit: A compound circuit in which a number of separate sources or electrically operated devices, or both, have all their positive poles connected to a single positive conductor and all their negative poles to a single negative conductor.

N

N.A.A.M.: Abbreviation for National Association of Automobile Manufacturers.

Naphtha: A product of the distillation of petroleum used to some extent for marine engines.

Needle Valve: A valve in a carbureter used for regulating the amount of gasoline to flow in with the mixture.

Negative Plate: Plate of a storage battery to which current returns from the outside circuit.

Negative Pole: That pole of an electric source through which the current is assumed to enter or flow back into the source after having passed through the circuit external to the source.

Neutral Position: The position of the change-speed lever which so places the gears that the motor may run idle, the car remaining still.

Non-Deflatable Tire: See "Tire, Non-Puncturable".

Non-Freezing Solution: A solution placed into the radiator of a motor car to prevent the water therein from freezing. Alcohol and glycerine are the usual anti-freezing agents. See "Anti-Freezing Solution".

Non-Puncturable Tire: See "Tire, Non-Puncturable".

Non-Skid Device: See "Anti-Skid Device".

O

Odometer: (1) The mileage-recording mechanism of a speedometer. (2) An instrument to be attached to an automobile wheel to automatically indicate the distance traveled.

Odometer, Hub: A speed-recording device which is placed on the hub cap of a wheel.

Offset: Off center, as a crankshaft in which a line vertically through the crankpins does not coincide with a line vertically through the center of the cylinder.

Ohm: (1) Unit of electrical resistance. (2) Amount of electrical resistance. Such resistance as would limit the flow of electricity under an electromotive force of one volt to a current of one ampere.

Ohm's Law: The law which gives the relation between voltage, resistance, and current flow in any circuit. Expressed algebraically, $C = \frac{I}{R}$ where C is the current flowing in amperes, I the voltage and R the ohmic resistance.

Oil Burner: A burner equipped with an atomizer for breaking up liquid fuel into a spray.

Oil Engine: An internal-combustion motor using kerosene or other oil as fuel.

Oil Gage: (1) A gage to indicate the flow of oil in the lubricating system. (2) Used to show the level of oil in a compartment in the base of a gas engine.

Oil Gun: A cylinder with a long point and a spring plunger for squirting oil or grease into inaccessible parts of a machine.

Oil Pump: A small force pump providing a constant positive supply of oil under pressure; usually considered to be more reliable than a lubricator.

Oiler: An automobile device for oiling machinery.

Opposed Motor: A gasoline engine whose cylinders are arranged in pairs on opposite sides of the crankshaft, both connecting rods of each pair being connected to the same crank, so that the shock of the explosion in one will be balanced by the cushioning effect of the compression in the other. In general these motors are two-cylinder, horizontal.

Otto Cycle: See "Four-Stroke Cycle".

Outside Spark Gap: See "Spark Gap, Outside".

Overcharged: The state of the storage battery when it has been charged at too high a rate or for too great a length of time.

Overhead Camshaft: A camshaft which is placed above the cylinder of a gas engine.

Overhead Valves: See "Motor, Overhead Valve".

Overheating: The act of allowing the motor to reach an excessively high temperature due to the heat of combustion being not carried away rapidly enough by the cooling devices, or to insufficient lubrication. Overheating of a bearing is due to insufficient lubrication.

P

Packing: The material introduced between the parts of couplings, joints, or valves, to prevent the leakage of gas or liquids to or from them.

Panel, Charging: A small switchboard for charging a storage battery.

Parallel Circuit: See "Multiple Circuit".

Patch, Tire-Repair: Rubber strips for making repairs in punctured or ruptured tires.

Petcock: A control cock which when open allows gas or liquid to escape from the chamber to which it is attached.

Petrol: Word used in England for gasoline.

Picric Acid: Acid which may be added to gasoline to increase the motor efficiency. Gasoline will absorb about five per cent of its weight of picric acid.

Pin, Taper: A conically shaped pin.

Pinch: A cut in an inner tube caused by the tube being caught or pinched between the outer casing and the rim.

Pinion: (1) The smaller of any pair of gears. (2) A small gear made to run with a larger gear.

Piston: The hollow, cylindrical portion attached to the connecting rod of a motor. The reciprocating part which takes the strain caused by the explosion.

Piston Air Valve: A secondary air valve in the piston of earlier types of gas engines to compensate the imperfect operation of surface carbureters used with those engines and to secure the injection of a sufficient quantity of air to insure the combustion of the charge.

Piston Head: The top of the piston.

Piston Pin: A pin which holds the connecting rod to the piston.

Piston Ring: (1) A metal ring inserted in a groove cut into a piston assisting in making the latter tight in the cylinder. There are usually three rings on each piston. (2) Rings about the circumference of a piston, whose diameter is slightly greater than that of the piston. These are to insure closer fit and prevent wearing of the piston, as the wear is taken up by the rings which may be easily removed.

Piston Rod: Usually called connecting rod. The rod which connects the piston with the crankshaft.

Piston Skirt: The portion of a piston below the piston pin.

Piston Speed: The rate at which the piston travels in its cylinder.

Piston Stroke: The complete distance a piston travels in its cylinder.

Pitted: Condition of a working surface which has become covered with carbon particles which have been imbedded in the metal.

Planetary Gear: An arrangement of spur and annular gears in which the smaller gears revolve around the main shaft as planets revolve around the sun.

Planetary Transmission: A transmission system in which the speed changes are obtained by a set of planetary gears.

Plate: Part of a storage battery which holds active material. See "Negative Plate".

Pneumatic Tire: A tire fitted to the wheels of automobiles, consisting usually of two tubes, the outer of India rubber, canvas, and other resilient wear-resisting material, and the inner composed of nearly pure rubber which is inflated with compressed air to maintain the outer tube in its proper form under load.

Polarizing: Formation of gas at the negative element of a cell so as to prevent the action of the battery. This formation of gas is caused by the violent reaction taking place in a circuit of low resistance.

Pole Piece: A piece of iron attached to the pole of a magneto used in an electric generator.

Poppet Valve: A disk or drop valve usually seating itself through gravitation or by means of springs, and frequently opening by suction or cams.

Port: An opening for the passage of the working fluid in an engine.

Portable Garage: See "Garage, Portable".

Positive Connection: A connection by which positive motion is transmitted by means of a crank, bolt, or key, or other method by which shipping is eliminated.

Positive Motion: Motion transmitted by cranks or other methods in which slipping is eliminated.

Positive Plate: Plate in a storage battery, from which the current flows to the outside circuit.

Positive Pole: The source from which electricity is assumed to flow; the opposite of negative pole. In a magnet the positive pole is the end of the magnet from which the magnetic flux is assumed to emanate.

Pounding in Engine: Pounding noise at each revolution, usually caused by either carbon deposit, loose or tight piston, loose bearing or other part, or pre-ignition.

Power Stroke: The piston stroke in a gas engine in which the exploded gases are expanding, thus pushing the piston downward.

Power Tire Pump: A pump which is operated by a gas engine and is used to inflate the tires of a motor car.

Power Unit: The engine with fuel, cooling, lubrication, and ignition systems, without the transmission or running gears. Sometimes the gearset and driving shaft are included by the term.

Pre-Ignition: See "Premature Ignition".

Premature Ignition: Ignition of fuel before the proper point in the cycle.

Pressure-Feed: See "Lubrication, Force-Feed".

Pressure Gage: A gage for indicating the pressure of a fluid confined in a chamber, such as steam in a boiler, etc.

Pressure Lubricator: A lubricating device in which the oil is forced to the bearings by means of a pump or other device for maintaining pressure.

Pressure Regulator: A device for maintaining the pressure of the steam in the principal pipe at a constant point irrespective of the fluctuations of pressure in the boiler.

Primary Air Inlet: The main or fixed air intake of a carbureter.

Primary Circuit: The circuit which carries low-tension current.

Primary Coil: A self-induction coil consisting of several turns of wire about an iron core.

Primary Spark Coil: An induction coil which has only a single winding composed of a few layers of insulated copper wire wound on a bundle of soft iron wires, known as the *core*, also as a *wipe*, or *touch, spark coil.*

Primer: A pin in a float-feed valve so arranged that it may depress the float in priming a gasoline engine. Also called *tickler* and *flushing pin.*

Priming: (1) The carrying of water over with the steam from the boiler to the engine, due to dirty water, irregular evaporation, or forced steaming. (2) Injecting a small amount of gasoline into the cylinder of a gasoline engine to assist in starting.

Priming Cock: A control cock screwed into the cylinder and which when open communicates with the combustion chamber allowing gasoline to be poured into the cylinder.

Progressive Change-Speed Gears: Change-speed gears so arranged that higher speeds are obtained by passing through all the intermediate steps and *vice versa.*

Prony Brake: A dynamometer to indicate the horsepower of an engine. A band encircles the flywheel of the engine and is secured to a lever, at the other end of which is a scale to measure the pull.

Propeller Shaft: The shaft which turns the rear axle of a motor car. The drive shaft.

Pump, Centrifugal: A pump with a hollow hub and curved blades which by centrifugal force throw water or oil into the system requiring it.

Pump, Circulation: See "Circulation Pump".

Pump, Fuel-Feed: A mechanically operated pump for insuring positive feed of fuel to the burner of a steam engine or carbureter of a gas engine.

Pump, Oil: See "Oil Pump".

Pump, Plunger: Sometimes called piston pump. One containing a piston which forces a liquid to a system.

Pump, Power Tire: See "Tire Pump".

Pump, Steam Boiler-Feed: See "Boiler-Feed Pump".

Pump, Water Circulating: See "Circulation Pump".

Pump Gear: A pump composed of two gears in mesh placed in a housing. When the gears revolve they carry oil or water, as the case may be, on their teeth, which deliver it to an outlet.

Puncture: The perforation of an inflated rubber automobile tire by some sharp substance on the roadbed.

Puncture-Closing Compound: A viscous compound placed within the inner tire tube to close the hole caused by a puncture.

Push Rod: A rod which operates the valves of a poppet-valve motor. A rod which imparts a pushing motion.

R

Race: (1) The parts upon which the balls of a ball bearing roll. (2) When referring to a gas engine, to operate at high speed without a load.

Racing Body: A low, light automobile body, having two seats with backs as low as possible; designed for large fuel capacity and very high speed.

Radiator: A device consisting of a large number of small tubes, through which the heated water from the jacket of the engine passes to be cooled, the heat being carried away from the metal of the radiator by air.

Radiator, Cellular: See "Honeycomb Radiator".

Radiator, Tubular: A radiator consisting of many tubes, through which water passes to be cooled.

Radiator Protector: See "Bumper".

Radius Rod: A bar in the frame of an automobile to assist in maintaining the proper distance between centers. Also called *distance rod*.

Rawhide Gear: Tooth gears, built up of compressed rawhide, used for high-speed drive. Sometimes a metal gear is merely faced with rawhide for the purpose of reducing noise.

Reach Rod: See "Radius Rod".

Reciprocating Parts: The parts such as pistons and connecting rods which have a reciprocating motion.

Rectifier, Alternating-Current: See "Current Rectifier".

Relief Cock: See "Compression-Relief Cock".

Removable Rim: See "Demountable Rim".

Resiliency: That property of a materia by virtue of which it springs back or recoils on removal of pressure, as a spring.

Resistance, Electrical: (1) A part of an electric circuit for the purpose of opposing the flow of the current in the circuit. (2) The electrical resistance of a conductor is that quality of a conductor by virtue of which the conductor opposes the passage of electricity through its mass. Its unit is the *ohm*.

Retard: With reference to the ignition system, causing the spark to occur while the piston is retarding or moving downward on the working stroke.

Retarding Ignition: See "Ignition, Retarding".

Retarding the Spark: See "Ignition, Retarding".

Retread: To replace the tread of a pneumatic tire with a new one.

Reverse Cam: On a gasoline engine a cam so arranged that by reversing its motion or shifting it along its shaft it will operate the valves and cause the engine to reverse.

Reverse Gear: In a steam engine, a device by which the valves may be set to effect motion of the car in either direction. In a gasoline automobile, the reversing gear is usually incorporated with the change-speed gears.

Reverse Lever: A lever by which the direction of movement of the driving wheels may be reversed without reversing the engine. This is usually combined with the change-speed levers.

Rheostat: A device for regulating the flow of current in a closed electrical circuit by introducing a series of graduated resistances into the circuit.

Rim: The portion of a wheel to which a solid or pneumatic tire is fitted. A circular, channel-shaped portion attached to the wheel felloe.

Rim, Demountable: A rim which may be removed from the wheel easily in order that another with an inflated tire may take its place.

Rim, Quick-Detachable: A rim made of two or more parts so that the tire may be detached and attached quickly.

Rim, Removable: See "Demountable Rim".

Road Map: A map of a section or locality showing the best roads for motor-car travel, and usually the best stopping places and repair stations.

Roadster: A small motor car designed to be fairly speedy; usually has carrying capacity for an extra large quantity of fuel and supplies; generally seats two persons, with provision for one or two more, by the attachment of a rumble seat in the rear.

Rocker Arm: A pivoted lever used to operate overhead valves in a T-head motor.

Rod, Radius: See "Radius Rod".

Rod, Steering: See "Steering Rod".

Roller Bearings: See "Bearing, Roller".

Roller Chain: A chain whose links are provided with small rollers to decrease the friction and the noise.

Rotary Valve: A type of valve somewhat similar to the Corliss engine valve used on automobile motors.

Rumble: A small single seat to provide for an extra passenger on a two-seated vehicle. Usually detachable.

Runabout: A small two-seated vehicle, usually of a lower power and lower speed, as well as lower operating radius, than a roadster.

Running Board: A horizontal step placed below the frame and used to assist passengers in leaving and entering a motor car.

Running Gear: The frame, springs, motor, wheels, speed-change gears, axles, and machinery of an automobile, without the body; used synonymously with *chassis*.

S

Safety Plug: See "Fusible Plug".

Safety Valve: A valve seated on the top of a steam boiler, and loaded so that when the pressure of the steam exceeds a certain point the valve is lifted from the seat and allows the steam to escape.

Saturated Steam: The quality of the steam when no more steam can be made in the closed vessel without raising the temperature or lowering the pressure.

Scavenging: The action of clearing the cylinder of an internal-combustion motor of the burned-out gases.

Score: To burn, or abrade a moving part with another moving part.

Screw: An inclined plane wrapped around a cylinder; a cylinder having a helical groove cut in its surface.

Searchlight: A headlight designed to throw a very bright light on the road. Electricity or acetylene is usually used as an illuminant, and the lamp has a parabolic reflector and may be turned to throw the light in any direction.

Secondary Battery: See "Accumulator".

Secondary Circuit: A circuit in which the electromotive force is generated by induction from a primary circuit in which a variable current is flowing. The high-tension circuit of a jump-spark ignition system.

Secondary Circuit: The circuit which carries high-tension current.

Secondary Spark Coil: An induction coil having a double winding upon its core. The inner winding is composed of a few layers of insulated wire of large size, and the outer winding consists of a great many layers of very small insulated copper wire. Also known as a *jump-spark coil*.

Seize: Refers to moving parts which adhere because of operation without a film of oil between the working surfaces.

Selective Change-Speed Gears: Change-speed gears so arranged that any desired speed combination can be obtained without going through the intermediate steps.

Self-Firing: Ignition of the mixture in a gas engine due to the walls of the cylinder or particles attached to them becoming overheated and incandescent.

Self-Starter: See "Engine Starter".

Separator, Steam: A device attached to steam pipes to separate entrained water from live steam before it enters the engine, or to separate the oily particles from exhaust steam on its way to the condenser.

Series Circuit: A compound circuit in which the separate sources or the separate electrical receiving devices, or both, are so placed that the current supplied by each, or passed through each, passes successively through the other circuits from the first to the last.

Set Screw: A small screw with a pointed end used for locking a part in a fixed position to prevent it from turning.

Setting Valves: See "Valve Setting".

Shaft, Intermediate: The shaft placed between the first and third motion gearing and acting as a carrier of motion between the two.

Shaft Drive: System of power transmission by means of a shaft.

Shim: See "Liner".

Shock Absorber: A device attached to the springs or hangers of motor cars to decrease the jars due to rough roads, instead of allowing them to be transmitted to the frame of the carriage.

Short Circuit: A shunt or by-path of comparatively small resistance around a portion of an electric circuit, by which enough current passes through the new path to virtually cut out the part of the circuit around which it is passed, and prevent it from receiving any appreciable current.

Sight Feed: An indicator covered with glass which shows that oil is flowing in a system. A telltale sight. A check on the oiling system.

Side-Bar Steering: See "Steering, Side-Bar".

Side-Slipping: See "Skidding".

Silencer: See "Muffler, Exhaust".

Silent Chain: A form of driving chain in which the links are comprised of sections which so move over the sprocket that practically all noise is eliminated. Silent chains are used specially for driving timing gears, gearsets, etc.

Skidding: The tendency of the rear wheels to slide sideways to the direction of travel, owing to the slight adhesion between tires and the surface of the roadbed, also called *side-slipping*.

Skip: See "Miss".

Sleeve Valve: A form of valve consisting of cylindrical shells moving up and down in the cylinders of such a motor as the Silent Knight.

Sliding Gears: A change-speed set in which various gears are placed into mesh by the sliding on a shaft of one or more gears.

Sliding Sleeve: See "Motor, Sleeve-Valve".

Slip Cover: A fabric covering for the top when down or for the upholstery of a motor vehicle.

Smoke in Exhaust: Smoky appearance in the exhaust due to too much oil, too rich mixture, low grade of fuel, or faulty ignition.

Solid Tire: See "Tire, Solid".

Sooting of Spark Plug: Fouling of the spark plug with soot, due to poor mixture, impure fuel, or improper lubrication.

Spare Wheel: An extra wheel complete with inflated tire, carried on the car for quick replacement of wheel with damaged tire.

Spark, Advancing: See "Advanced Ignition".

Spark Coil: A coil or coils of wire for producing a spark at the spark plug. It may be either a secondary or primary spark coil.

Spark Gap: A break in the circuit of a jump-spark ignition system for producing a spark within the cylinder to ignite the charge. The spark gap is at the end of a small plug called the *spark plug*.

Spark Gap, Extra: See "Spark Gap, Outside".

Spark Gap, Outside: A device to overcome the short circuiting in the spark gap due to fouling and carbon deposits between the points of the high-tension spark plug. It is a form of condenser, or capacity in which the air acts as the dielectric between two surfaces at the terminals of a gap in a high-tension circuit.

Spark Intensifier: See "Spark Gap, Outside".

Spark Lever: See "Timing Lever".

Spark Plug: The terminals of the secondary circuit of a jump-spark ignition system mounted to leave a spark gap between the terminals projecting inside the cylinder for the purpose of igniting the fuel in the cylinder by means of a spark crossing the gap between them.

Spark Plug, Pocketing: Mounting the spark plug in a recess of the cylinder head to reduce the sooting of the sparking points.

Spark Plug, Sooting of: See "Sooting of Spark Plug".

Spark Regulator: A mechanism by which the time of ignition of the charge is varied by a small handle on or near the steering wheel.

Spark, Retarding: See "Ignition, Retarding".

Spark Timer: See "Timer, Ignition".

Speaking Tube: See "Annunciator".

Specific Gravity: The weight of a given substance relative to that of an equal bulk of some other substance which is taken as a standard of comparison. Air or hydrogen is the standard for gases, and water is the standard for liquids and solids.

Specific Heat: The capacity of a substance for removing heat as compared with that of another which is taken as a standard. The standard is generally water.

Speed-Change Gear: A device whereby the speed ratio of the engine and driving wheels of the car is varied.

Speed Indicator: An instrument for showing the velocity of the car.

Speedometer: A device used on motor cars for recording the miles traveled and for indicating the speed at all times.

Speedometer Gears: Gears used to drive a shaft which operates the speedometer.

Speedometer Shaft: A flexible shaft which operates a speedometer.

Spiral Gear: A gear with helically-cut teeth.

Splash Lubrication: See "Lubrication, Splash".

Spline: A key.

Spontaneous Ignition: See "Self-Firing".

Sprag: A device to be let down (usually at the rear of the car) to prevent its slipping back when climbing a hill.

Spray Nozzle: That portion of a carbureter which sprays the gasoline.

Spring: An elastic body, as a steel rod, plate, or coil, used to receive and impart power, regulate motion, or diminish concussion.

Spring, Cantilever: A type of spring which appears like a semi-elliptic reversed; and which is flexibly attached in the center, rigidly at one end, and by a shackle at the other.

Spring, Elliptic: A spring, elliptic in shape, and consisting of two half-elliptic members attached together.

Spring Semi-Elliptic: A spring made up of a number of leaves, the whole resembling a portion of an ellipse.

Spring, Supplementary: See "Shock Absorber".

Spring, Underslung: A spring which is fastened under the axle instead of over it.

Spring Hangers: See "Body Hangers".

Spring Shackle: A link attached to one end of a spring which allows for flattening of the spring.

Sprocket: A wheel with teeth around the circumference, so shaped that the teeth will fit into the links of a chain which drives or is driven by the sprocket.

Starboard: The right-hand side of a ship or vessel.

Starter, Engine: See "Engine Starter".

Starting, Gas Engine: The operation necessary to make the engine automatically continue its cycle of events. It usually consists of opening the throttle, retarding the spark, closing the ignition circuit, and cranking the engine.

Starting Crank: A crank by which the engine may be given several revolutions by hand in order to start it.

Starting Device: See "Engine Starter".

Starting on Spark: In engines having four or more cylinders with well-fitting pistons, it is often possible to start the motor after it has stood idle for some time by simply closing the ignition circuit, provided that the previous stopping of the engine was done by opening the ignition circuit before the throttle was closed, leaving an unexploded charge under compression in one of the cylinders.

Steam: The vapor of water; the hot invisible vapor given off by water at its boiling point.

Steam Boiler: See "Boiler".

Steam Condenser: See "Condenser".

Steam, Cycle of: A series of operations of steam forming a closed circuit, a fresh series beginning where another ends; that is, steam is generated in the boilers, passes through the pipes of the engine, doing work successively in its various cylinders, escaping at exhaust pressure to the condenser, where it is converted into water and returned to the boiler, to go through the same operations once more.

Steam Engine: A motor depending for its operation on the latent energy in steam.

Steam Gage: See "Pressure Gage".

Steam Port: See "Admission".

Steering, Side-Bar: Method of guiding the car by means of an upright bar at the side of the seat.

Steering Angle for Front Wheels: Maximum angle of front wheels to the axle when making a turn; should be about 35°.

Steering Check: A device for locking the steering gear so that the direction will not be changed unless desired.

Steering Column: See "Steering Post".

Steering Gear: The mechanism by which motion is communicated to the front axle of the vehicle, by which the wheels may be turned to guide the car as desired.

Steering Knuckle: A knuckle connecting the steering rods with the front axle of the motor.

Steering Lever: A lever or handle by which the car is guided.

Steering Neck: The vertical spindle carried by the steering yoke. It is the pivot of the bell crank by which the wheel is turned.

Steering Pillar: See "Steering Post".

Steering Post: The member through which the twist of the steering wheel is transmitted to the steering knuckle. The steering post often carries the spark and throttle levers also.

Steering Rod: The rod which connects the steering gear with the bell cranks or pivot arms, by means of which the motor car is guided.

Steering Wheel: The wheel by which the driver of a motor car guides it.

Steering Yoke: The Y-shaped piece in which the front axle terminates. The yoke carries the vertical steering spindle or steering neck.

Stephenson Link Motion: A reversing gear in which the ends of the two eccentric rods are connected by a link or quadrant sliding over a block at the end of the valve spindle.

Step-Up Coil: A coil used to transform low- into high-tension current.

Storage Battery: See "Accumulator".

Stroke: See "Piston Stroke".

Strainer, Gasoline: A wire netting for preventing impurities entering the gasoline feed system.

Strangle Tube: The narrowing of the throat of the carbureter just above the air inlets in order to increase the speed of the air, and thus increase the proportion of gas which will be picked up.

Stroke: The distance of travel of a piston from its point of farthest travel at one end of the cylinder to its point of farthest travel at the other end. Two strokes of the piston take place to every revolution of the crankshaft.

Stud Plate: The plate or frame in a planetary transmission system carrying studs upon which the central pinions revolve.

Suction Valve: The type of admission valve on an internal combustion engine which is opened by the suction of the piston within the cylinder and admits the mixture. The valve is normally held to its seat by a spring.

Sulphating of Battery: The formation of an inactive coating of lead sulphate on the surface of the plates of a storage battery. It is a source of loss in the battery.

Superheated Steam: Steam which has been still further heated after reaching the point of saturation.

Supplementary Air Valve: See "Auxiliary Air Valve".

Swivel Joint: The joint for connecting the steering arm of the wheel or lever-steering mechanism to the arms on the steering wheel. Also called *knuckle joint*.

T

Tachometer: An instrument for indicating the number of revolutions made by a machine in a unit of time.

Tandem Engine: A compound engine having two or more cylinders in a line, one behind the other, and with pistons attached to the same piston rod.

Tank Gage: See "Fuel-Level Indicator".

Tappet Rod: See "Push Rod".

Taxicab: A public motor-driven vehicle in which the fare is automatically registered by the taximeter.

Taximeter: An instrument in a public vehicle for mechanically indicating the fare charged.

Terminals: The connecting posts of electrical devices, as batteries or coils.

Thermal Unit: Usually called the *British Thermal Unit*, or *B. t. u.* A measure of mechanical work equal to the energy required to raise one pound of water one degree Fahrenheit.

Thermostat: An instrument to automatically regulate the temperature.

Thermosiphon Cooling: A method of cooling the cylinder of a gas engine. The water rises from the jackets and siphons into a radiator from whence it returns to the supply tank, doing away with the necessity for a circulating pump.

Three-Point Suspension: A method used for suspending motor car units, such as the motor, on three points.

Throttle: A valve placed in the admission pipe between the carbureter and the admission valve of the motor to control the speed and power of the motor by varying the supply of the mixture.

Throttle, Foot: See "Accelerator".

Throttle, Lever: A lever on the steering wheel which operates the carbureter throttle. See "Throttle".

Throttling: The act of closing the admission pipe of the engine so that the gas or steam is admitted to the cylinder less rapidly, thus cutting down the speed and power of the engine.

Thrust Bearing: A bearing which takes loads parallel with the axis of rotation of the shaft upon which it is fitted.

Tickler: A pin in a carbureter arranged to hold down the float in priming, also called *flushing pin* and *primer*.

Timer, Ignition: An ignition commutator.

Timing Gears: The gears which operate the camshaft and magneto shaft. The camshaft gear is twice as large as the crankshaft gear.

Timing Lever: A lever fitted to gas engines by means of which the time of ignition is changed. Also called *spark lever*.

Timing Valve: In a gas engine using float-tube ignition, a valve controlling the opening between the combustion space and the igniter.

Tip, Burner: A small earthen, aluminum, or platinum cover for the end of the burner tube of an acetylene lamp. It is usually provided with two holes, so placed that the jets from them meet and spread out in a fan shape.

Tire, Airless: See "Airless Tire".

Tire, Clincher: A type of pneumatic tire which is held to a clincher.

Tire, Cushion: Vehicle tire having a very thick rubber casing and very small air space. It is non-puncturable and does not have to be inflated, but is not as resilient as a pneumatic tire.

Tire, Non-Deflatable: See "Tire, Non-Puncturable".

Tire, Non Puncturable: A tire so constructed that it cannot be easily punctured or will not become deflated when punctured.

Tire, Punctures in: Holes or leaks in pneumatic tires caused by foreign substances penetrating the inner tube and allowing the air to escape.

Tire, Single-Tube: A pneumatic tire in which the inner and outer tubes are combined.

Tire, Solid: A tire made of solid, or nearly solid rubber.

Tire Band: A band to protect or repair a damaged pneumatic tire. See "Tire Protector".

Tire Bead: Lower edges of a pneumatic tire which grip the curved portion of a rim.

Tire Case: (1) A leather or metal case for carrying spare tire; same as *tire holder*. (2) The outer tube.

Tire Chain: See "Anti-Skid Device".

Tire Filling: Material to be introduced into the tire to take the place of air and do away with puncture troubles

Tire Gage: Gage used for measuring the air pressure in a pneumatic tire.

Tire Holder: A metal or leather case for carrying spare tires.

Tire-Inflating Tank: A tank containing compressed air or gas for inflating the tires.

Tire Inflater, Mechanical: A small mechanical pump for inflating pneumatic tires.

Tire Patch: See "Patch, Tire Repair".

Tire-Pressure Gage: A pressure gage to indicate the pressure of air in the tire.

Tire Protector: The sleeve or band placed over a tire to protect it from road wear.

Tire Pump: A pump for furnishing air under pressure to the tire, may be either hand- or power-operated.

Tire Sleeve: A sleeve to protect the injured part of a pneumatic tire. It is a tire protector which covers more of the circumference of the wheel than a tire band. See "Tire Protector".

Tire Tape: Adhesive tape used to bind the outer tube to the rim in repairing tires.

Tire Tool: Tool used to apply and remove a tire.

Tire Valve: A small valve in the inner tube to allow air to be pumped into the tube without permitting it to escape.

Tires, Creeping of: See "Creeping of Tires".

Tonneau: The rear seats of a motor car. Literally, the word means a round tank or water barrel.

Torque: Turning effort, or twisting effort of a rotating part.

Torque Rod: A rod attached at one end to the rear axle and at the other to the frame; used to prevent twisting of the rear-axle housing.

Torsion Rod: The shaft that transmits the turning impulse from the change gears to the rear axle. Usually spoken of as the *shaft*.

Touch Spark: See "Wipe Spark".

Tourabout: A light type of touring car.

Touring Car: A car with no removable rear seats, and a carrying capacity of four to seven persons.

Town Car: A car having the rear seats enclosed but the driver exposed.

Traction: The act of drawing or state of being drawn. The pull (or push) of wheels.

Tractor: A self propelled vehicle for hauling other vehicles or implements; a traction engine.

Transmission, Individual Clutch: A transmission consisting of a set of spur gears on parallel shafts which are always in mesh, different trains being picked up with a separate clutch for each set.

Transmission, Planetary: A transmission system in which a number of pinions revolve about a central pinion in a manner similar to the revolution of the planets about the sun; usual type consists of a central pinion surrounded by three or more pinions and an internal gear.

Transmission, Sliding Gear: A transmission system in which sliding change-speed gears are used.

Transmission Brake: Brake operating on the gearset shaft or end of the propeller shaft.

Transmission Gears: A set of gears by which power is transmitted. In automobiles, usually called *change-speed gears*.

Transmission Ratio: The ratio of the speed of the crankshaft to the speed of the transmission shaft or driving shaft.

Tread: That part of a wheel which comes in contact with the road.

Tread, Detachable: A tire covering to protect the outer tube, which may be taken off or replaced.

Trembler: The vibrating spring actuated by the induction coil magnet which rapidly connects and disconnects the primary circuit in connection with jump-spark ignition.

Truck: (1) A strong, comparatively slow-speed vehicle, designed for transporting heavy loads. (2) A swiveling carriage having small wheels, which may be placed under the wheels of a car.

Try Cock: A faucet or valve which may be opened by hand to ascertain the height of water in the boiler.

Tube Case: See "Tire Case".

Tube Ignition: See "Hot-Tube Ignition".

Tubing, Flexible: See "Flexible Tubing".

Tubular Radiator: An automobile radiator in which the jacket water circulates in a series of tubes.

Tungsten Lamp: Incandescent bulb with the filament made of tungsten wire.

Turning Moment: See "Torque".

Turning Radius: The radius of a circle which the wheels of a car describe in making its shortest turn.

Turntable: Device installed in the floor of a garage and used for turning motor cars around.

Two-Cycle or Two-Stroke Cycle Engine: An internal-combustion engine in which an impulse occurs at the beginning of every revolution, that is, at the beginning of every downward stroke of the piston.

Two-to-One Gear: The system of gearing in a four-cycle gas engine for driving the camshaft, which must revolve once to every two revolutions of the crankshaft.

U

Under Frame: The main frame of the chassis or running gear of a motor vehicle.

Unit-Power Plant: A power system consisting of a motor, gearset, and clutch which may be removed from the motor car as a unit.

Universal Joint: A mechanism for endwise connection of two shafts so that rotary motion may be transmitted when one shaft is at an angle with the other. Also called *universal coupling, flexible coupling, Cardan joint* and *Hooke's joint*.

Upkeep: The expenditure for maintenance or expenditure required to keep a vehicle in good condition and repair.

V

Vacuum Fuel Feed: A system of feeding the gasoline from a tank at the rear of an automobile by maintaining a partial vacuum at some point in the system, usually at the dash, the fuel flowing from this point by gravity to the carbureter.

Vacuum Line: In an indicator diagram, the line of absolute vacuum. It is at a distance corresponding to 14.7 pounds below the atmospheric line.

Valve: A device in a passage by which the flow of liquids or gases may be permitted or stopped.

Valve, Admission: The valve in the admission pipe of the engine leading from the carbureter to the cylinder by which the supply of fuel may be cut off.

Valve, Automatic: See "Automatic Valve".

Valve, Inlet: See "Inlet Valve".

Valve, Mixing: See "Mixing Valve".

Valve, Muffler Cut-Out: See "Cut-Out, Muffler".

Valve, Overhead: See "Overhead Valve".

Valve, Poppet: See "Poppet Valve".

Valve, Rotary: See "Motor, Rotary Valve".

Valve, Suction: An admission valve which is opened by the difference between the pressures in the atmosphere and in the cylinder.

Valve Cage: A valve-retaining pocket which is attached to the cylinder.

Valve Clearance: The clearance of play between the valve stem and the tappet.

Valve Gear: The mechanism by which the motion of the admission or exhaust valve is controlled.

Valve Grinding: The act of removing marks of corrosion, pitting, etc., from the seats and faces of poppet or disk valves. The surfaces to be ground are rotated in contact with each other, an abrasive having been supplied.

Valve Lift: See "Lift".

Valve Lifter: A device for raising a poppet valve from its seat.

Valve Seat: (1) That portion of the engine upon which the valve rests when it is closed. (2) The portion upon which the face of a valve is in contact when closed.

Valve Setting: The operation of adjusting the valves of an engine so that the events of the cycle occur at the proper time. Also called *valve timing*.

Valve Spring: The spring which is around the valve stem and is used to return the valve to closed position after it has been opened by the cam:

Valve Stem: The rod-like portion of a poppet valve.

Valve Timing: See "Valve Setting".

Vaporizer: A device to vaporize the fuel for an oil engine. In starting it is necessary to heat the vaporizer, but the exhaust gases afterwards keep it at the proper temperature. The carbureter of the gas engine properly belongs under the general head of *vaporizer*, but the term has become restricted to the vaporizer for oil engines.

Variable-Speed Device: See "Gear, Change-Speed".

Vertical Motor: An upright engine whose piston travel is in a vertical plane.

Vibrator: The part of the primary circuit of a jump-spark ignition system by which the circuit is rapidly interrupted to give a transformer effect in the coil.

Vibrator, Master: See "Master Vibrator".

Volatile: Passing easily from a liquid to a gaseous state, in opposition to *fixed*.

Volatilization: Evaporation of liquids upon exposure to the air at ordinary temperatures.

Volt: Practical unit of electromotive force; such an electromotive force as would cause a current of one ampere to flow through a resistance of one ohm.

Voltammeter: A voltmeter and an ammeter combined; sometimes refers to wattmeter.

Voltmeter: An instrument for measuring the difference of electric potential between the terminals of an electric circuit. It registers the electric pressure in volts.

Vulcanization: The operation of combining sulphur with rubber at a high temperature, either to make it soft, pliable, and elastic, or to harden it.

Vulcanizer: A furnace for the vulcanization of rubber.

W

Walking Beam: See "Rocker Arm".

Water Cooling: Method of removing the heat of an internal-combustion motor from the cylinders by means of a circulation of water between the cylinders and the outer casing.

Water Gage: An instrument used to indicate the height of water within a boiler or other water system. It consists of a glass tube connected at its upper and lower ends with the water system.

Water Jacket: A casing placed about the cylinder of an internal-combustion engine to permit a current of water to flow around it for cooling purposes.

Watt: The unit of electric power. It is the product of the current in amperes flowing in a circuit by the pressure in volts. It is $\frac{1}{746}$ of a horsepower.

Watt Hour: The unit of electrical energy. The given watt-hour capacity of a battery, for instance, means the ability of a battery to furnish one watt for the given number of hours or the given number of watts for one hour, or a number of watts for a number of hours such that their product will be the given watt hours.

Welding, Autogeneous: A method of joining two pieces of metal by melting by means of a blow torch burning acetylene in an atmosphere of oxygen. This melts the ends of the parts and these are then run together.

Wheel, Artillery: A wood-spoked wheel whose spokes are in line with a line drawn vertically through the hub.

Wheel, Dished: A wheel made concave or convex so that the hub is inside or outside as compared with the rim. This is to counteract the outward inclination of the wheel due to the fact that the spindle is tapered and that its outward center is lower than its inner center.

Wheel, Double-Interacting: The mechanism by which two wheels are hung on one hub or axle, the outer being shod with an ordinary solid tire and the inner with a pneumatic tire, so that the weight of the vehicle bears against the lowest point of the pneumatic tire of the inner wheel to give the durability and tractive properties of a solid tire with the resiliency of a pneumatic.

Wheel, Spare: See "Spare Wheel".

Wheel Steering: See "Steering Wheel".

Wheel, Wire: A wheel with spokes made of wire.

Wheel Puller: A device used for pulling automobile wheels from their axles.

Wheel Steer: A method of guiding a car by means of a hand wheel.

Wheel, Steering Angle for: The angle which the steering column makes with the horizontal. It varies from 90° to 30° or less.

Wheelbase: The distance between the road contact of one rear wheel with the point of road contact of the front wheel on the same side.

Wheels, Driving on All Four: The method of using all four wheels of an automobile as the driving wheels.

Wheels, Driving on Front: The method of using the two front wheels as the drivers.

Wheels, Steering on Rear: Method of guiding the vehicle by turning the rear wheels.

Whistle: An automobile accessory consisting of a signalling apparatus giving a loud or harsh sound. Also called a *horn.*

Wind Guard: See "Wind Shield".

Wind Shield: A glass front placed upright on the dash to protect the occupants of the car from the wind.

Wipe Spark: Form of primary sparking device in which a spark is produced by a moving terminal sliding over another terminal, the break thus made causing a spark. Also called *touch spark.*

Wipe-Spark Coil: A primary spark coil with which the spark is made by wiping contact.

Wire Drawing: The effect of steam passing through a partially closed valve or other constricted opening; so called from the thinness of the indicator diagram.

Working Pressure: The safe working pressure of a boiler, usually estimated as ⅙ of the pressure at which a boiler will burst.

Worm: A helical screw thread.

Worm and Sector: A worm gear in which the worm wheel is not complete but is only a sector. Used especially in steering devices.

Worm Drive: A form of drive using worm gears. See "Gears, Worm".

Worm Gear: The spiral gear in which a worm or screw is used to rotate a wheel.

Worm Wheel: A wheel rotated by a worm.

Wrist Pin: See "Piston Pin".

X

X Spring: A vehicle spring composed of two laminated springs so placed one upon the other that they form the letter X.

Y

Yorke, Steering: See "Steering Yoke".

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

COMMERCIAL VEHICLES

PART V

1. Describe early forms of agricultural tractors.
2. Describe the Higgins carbureter.
3. Give details of the Samson transmission.
4. Describe the governor used in the International tractor.
5. Describe the Hart-Parr tractor, giving sizes, motor dimensions, speed of engine, etc.
6. Wherein does the Johnson differ from the Detroit tractor?
7. What is the special advantage of the caterpillar type? Give the details of construction.
8. What is a flash generator?
9. Describe the Stanley boiler.
10. Discuss coke as a fuel and describe one coke-fired steam wagon.
11. Why is alcohol not generally used as a fuel?
12. Is it possible to run an engine designed for gasoline or kerosene with alcohol as a fuel without structural change? Discuss.
13. Wherein does the carbureter designed for gasoline differ from the one designed for distillate?
14. Sketch a sectional view of the Holley gasoline carbureter.
15. Compare the cost per year of operating a 2500-pound vehicle with the cost of the number of horses which would be displaced by the use of such a machine.

16. How would you calculate depreciation on a commercial vehicle?

17. Discuss the adaptability of the professional chauffeur and of the teamster, as drivers of a commercial vehicle.

18. Describe the Pierce-Arrow hydraulic hoist.

19. Describe a good end-tipping unloading arrangement.

20. Describe the Peerless tipping mechanism.

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AUTOMOBILES

1. Define *radiation*, *absorption*, *conduction*, and *convection*.
2. What is absolute zero? What molecular state does it theoretically represent?
3. Discuss the location of the steam engine on automobiles.
4. Convert 65 degrees Fahrenheit into centigrade.
5. State Boyle's Law.
6. Define *force*, *work*, *power*, and *horsepower*.
7. Describe and sketch the action of an elementary slide valve.
8. Define British thermal unit.
9. Draw a theoretical indicator card for one-fourth cut-off.
10. Define *latent heat*. How many British thermal units are absorbed in boiling away a pound of water at atmospheric pressure?
11. Discuss the effect of compression on the indicator card of an engine.
12. Why is the explosion of a stationary boiler so destructive?
13. Define *superheat*. What is its object?
14. What is the purpose of condensers if used on steam cars?
15. Describe and sketch the Stephenson link valve motion.
16. Describe the Bunsen burner.
17. What is the object of the pilot light?
18. Describe the Ofeldt burner.
19. How are automobile boilers classified?
20. Explain the principles of the fire-tube boiler.
21. In what way do flash boilers differ from the other types?
22. For what purpose are check valves used and how are they constructed?
23. Sketch and describe the Stanley fuel system.
24. What is the purpose of the water-level indicator?

25. Explain the working conditions of the Stanley oil pump.

26. What general rules should be followed in the management of the steam car on the road?

27. Explain all the points which have to be considered in firing-up the boiler.

28. What is a fusible plug and what is its purpose?

29. What precautions are necessary in starting the burner?

30. Enumerate the causes of failure of the water pump to work.

REVIEW QUESTIONS

ON THE SUBJECT OF

MOTORCYCLES AND CYCLECARS LIGHT CARS

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1. How many cylinders has the conventional American motorcycle?
2. Describe the operation of a motorcycle.
3. Why is it so important that the valves of a motor be properly seated?
4. What are the principal points to be kept in mind in connection with the tires?
5. Describe the details of the Indian motorcycle.
6. What is the essential difference between the Pope motorcycle and other makes?
7. Sketch the Merkel spring frame construction.
8. How is the cooling of the motor usually effected on motorcycles?
9. Describe the two-speed sliding gear.
10. How is the oil fed in the Excelsior system?
11. What type of starter has been adopted on motorcycles?
12. What different kinds of brakes are employed on motorcycles?
13. How is the ignition arranged on motorcycles?
14. What are the three characteristic types of cyclecars?
15. Describe the Malcolm and Zip cyclecars.
16. Discuss how the cyclecar has developed into a light car.
17. Why was high speed necessary in the development of the light car?
18. Describe the Metz car.
19. What treads are used on light cars?

20. What type of cooling system is usually used on these cars?

21. Why is high engine speed impossible without proper balancing of the reciprocating parts?

22. What are the usual cylinder dimensions and strokes on cyclecars?

23. Show by sketches the different body types and seating arrangements for light cars.

24. Describe the transmission of the Scripps-Booth car.

25. What is the special feature of the Princess light car.

REVIEW QUESTIONS

ON THE SUBJECT OF

MOTOR BOATS

1. Upon what does the appearance of a boat depend?

2. Describe the construction of the water intake.

3. What are the essentials of the smallest Diesel engine built in the United States?

4. Give a definition of *displacement.*

5. Sketch and describe a water jacket.

6. Where is the muffler in large power boats usually located?

7. Define a *fathom,* a *knot,* and give their equivalents.

8. How may motors be classified?

9. What is the office of a governor?

10. Describe the Snow and Petrelli reversing gear.

11. Give general directions for the installing of the engine in a boat.

12. Compare the connecting rods of a medium-speed motor to those of high- and low-speed.

13. What are the fuels most commonly used in motors?

14. Define *center of buoyancy.*

15. What is the pitch and slip of a propeller?

16. In what sizes are Diesel engines usually built?

17. Give a clear explanation of the meaning of traverse metacenter.

18. Referring to the problem given on page 4, calculate the new draft of the cruiser if 15 tons are added instead of 10 tons, without changing her trim.

19. Make a sketch of the mid-ship section of the V-bottom cruiser.

20. Give illustrations of stable, unstable, and neutral equilibrium.

21. What signifies one short blast of the whistle?

22. What are the so-called fog signals?

23. Give a description of the Sterling high-speed motor.

GENERAL INDEX

GENERAL INDEX

In this Index the Volume number appears in Roman numerals—thus, I, II, III, IV, etc., and the Page number in Arabic numerals—thus, 1, 2, 3, 4, etc. For example, Volume IV, Page 327, is written, IV, 327.

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

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