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GOTTLIEB DAIMLER

(1834-1899)

INVENTOR OF THE PRACTICAL HIGH-SPEED GASOLINE MOTOR

AND

"FATHER OF THE AUTOMOBILE"

SECOND REVISED EDITION

SELF-PROPELLED VEHICLES

A PRACTICAL TREATISE

ON THE

THEORY, CONSTRUCTION, OPERATION, CARE
AND MANAGEMENT

OF ALL FORMS OF

AUTOMOBILES

BY

JAMES E. HOMANS, A. M.

WITH UPWARDS OF 500 ILLUSTRATIONS AND DIAGRAMS, GIVING THE ESSENTIAL DETAILS OF CONSTRUCTION AND MANY IMPORTANT POINTS ON THE SUCCESSFUL OPERATION OF THE VARIOUS TYPES OF MOTOR CARRIAGES DRIVEN BY STEAM, GASOLINE AND ELECTRICITY.

NEW YORK, U. S. A.
THEO. AUDEL & COMPANY
SIXTY-THREE FIFTH AVENUE
1905

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PREFACE.

IN presenting this second edition of "Self-Propelled Vehicles" to readers interested in automobile matters, and to the public in general, some few words of explanation are necessary. The automobile, considered as a practical machine, occupies a peculiar place, from both mechanical and popular points of view. It must be carefully designed and thoroughly equipped to serve its purposes under all the trying conditions of its use. It must, furthermore, be of simple and strong construction, so as to render disablements in service and consequent repairs—often at points distant from mechanics skilled in the special field—as few and as unimportant as possible. Last, but most conspicuous, it must be readily controlled and operated in the large majority of instances by persons who do not consider that the pleasures derived from "motoring" warrant them in becoming well-informed in engineering matters.

If the owner of a steam carriage burns out his boiler every time he takes an outing, he blames the builder of the machine rather than his own ignorance of steam engine theory and practice. If the owner of a gasoline carriage meets with any one of the several common accidents that result from simple carelessness and neglect, he forthwith announces that the automobile is not as yet a practical machine, and becomes a stalwart champion of the trusty horse, whom Nature herself repairs, so long as feed and water are not forgotten.

For the practical information of such persons as have neither the time nor inclination to delve deeper into the subtleties of mechanics than the construction and management of their own machine requires, this book has been planned.

The task is by no means an easy one, both from the multiplicity of details involved and from the constant necessity of making explanations that shall be perfectly clear. Furthermore, no book of reasonable compass could possibly include specific descriptions and directions for the management of even the majority of practical motor carriages now on the market. Nor would such a work be of general interest to the reading public. The best that can be done, therefore, is to give the principles of theory, construction and operation as briefly and explicitly as possible, and to illustrate them by the constructions used on such machines as have proved their title to be called typical.

It is hoped that the treatment given will make the book serviceable to owners and those desiring to qualify as practical chauffeurs, so far as the essential knowledge may be imparted by a book. There are, of course, many things that will not be perfectly clear without practical experience, also such divergencies of construction and operative method as will prove decidedly puzzling to the novice. However, by thoroughly understanding the principles on which all constructions necessarily rest these may rapidly be mastered.

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CHAPTER ONE.

TYPES AND MERITS OF AUTOMOBILES.

Types of Automobiles.—Within the last three years the construction of automobiles, or motor-propelled road vehicles has been greatly modified and improved in a number of particulars. The troubles that were previously notable are now very nearly overcome, and in the case of steam, electric and gasoline carriages alike the ideal of a perfectly practical machine is rapidly being approximated. Neither has this gradual development of the ideal vehicle involved any such radical changes as some superficial and ill-informed persons have confidently predicted. True to the statements of practical experts, the leading features—such as steering and compensating apparatus, rear-wheel drive, resilient tires, and several other features—have remained the same. Only the details have been altered and improved in the gradual evolution of the practical out of the experimental. Furthermore, the steady tendency is toward a greater uniformity of design, rather than toward any eccentric or novel constructions; toward a perfecting of standard constructions already recognized, rather than toward anything entirely new and peculiar.

In another respect the development of the practical road carriage is notable: and that is, that types formerly prevalent are gradually lapsing in popularity, while others are gaining in corresponding ratio. Thus, steam carriages, which a few years since were manufactured by nearly two-score different concerns in this country, are at present built by scarcely half that number, and are sold in very small numbers. The electrical vehicle has taken its logical position as a means of freight and passenger traffic in cities and for short tours out of town; while the gasoline machine is rapidly gaining recognition as the automobile *par excellence.* Such changes in popular estimate of the three types of driving power are based almost entirely upon practical considerations, quite independent of the arguments that may be adduced by interested authorities and enthusiasts. Furthermore, the foremost considerations in the mind of the motor-using public refer almost entirely to ease of care and control and immunity from disablement. This explains the present pre-eminence of the gasoline machine, in which the sole requirement for starting is to crank the engine, thus saving the troubles incident on starting the fire, as in the steamer, or on caring for and recharging the battery, as in the electric.

Advantages Analyzed.—In a recent number of a well-known automobile journal (*Motor,* New York), the several advantages of the three types of machine are set forth by prominent experts.

Speaking for the steam vehicle, Windsor T. White specifies the following twelve advantages: (1) Practical absence of jar and noise; (2) ease of control—throttling instead of gear shifting by levers; (3) absence of gearing between the engine and the drive axle; (4) flexibility of the steam engine, permitting any speed, from highest to lowest, with nearly even power efficiency; (5) continuous application of power in each cylinder, instead of a power stroke in each two revolutions, as with the four-cycle gasoline engine; (6) ease of lubrication in the comparatively cool cylinder, and absence of trouble from over-oiling; (7) the fact that the steam engine is better understood by the average man than either of the other motive powers; (8) from this reason, the greater ease of having roadside repairs made; (9) a combination of flash generator, automatic fuel regulation, compound engine and direct drive gives the most satisfactory machine for inexpert operators; (10) certain and invariable automatic regulation dependent solely on the physical properties of varying temperature and pressure; (11) complete elimination of boiler troubles, scaling, etc., by the use of the flash generator; (12) complete immunity from burning out, with the combination of flash generator and thermostatic regulation.

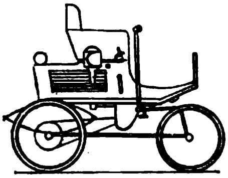
Mr. White is speaking, of course, of a carriage using the flash-line system of generation, as embodied in the machines built by his company, which have proved of the greatest advantage for this purpose since the time of Serpollet's first invention of this apparatus in 1889. With other types of generator and regulator the advantages are less conspicuous. Mervyn O'Gorman, an English authority, states the case of the average steam carriage from both sides. As ten advantages: (1) Absence of speed gears;

(2) saving of wear, tear and noise; (3) high power-outputs for short periods for climbing hills and traveling on rough roads; (4) greater speed uphill, and greater average speed for original cost; (5) proportionate fuel consumption and power efficiency; (6) cleanliness equal to petrol motors; (7) absence of the troublesome ignition system, as on petrol motors; (8) absence of exhaust noises, back-shots, pre-ignition, etc.; (9) cheapness in first cost; (10) starting without cranking, therefore stillness of the car in standing. As sixteen disadvantages: (1) The need of extinguishing the fire during stoppages; (2) the consequent trouble of re-igniting the burner; (3) the great loss of fuel, due to not extinguishing; (4) the need for greater attention, owing to the number of adjustments not automatic; (5) limited capacity for carrying fuel and water supply; (6) heavy fuel consumption, generally twice that of gasoline carriages of the same power; (7) heavy water consumption, and the need for constant refills; (8) fouling of the boiler tubes—in some types; (9) vitiation of the air by burned products in greater volume than with gasoline motors; (10) loss of time in starting from a cold boiler; (11) greater dangers from neglect, such as seizing and heating from insufficient lubrication, grave consequences in failure of water system, priming from high water and consequent knocking of the pistons, evil effects of feeding oil into any type of boiler or generator, clogging of valves or failure of pumps; (12) the troubles, due to wind blowing down upon the fire; (13) stoppage of safety valves; (14) necessity of using soft water for boilers; (15) trouble of cleaning the flues;.(16) issue of visible steam mixed with oil liable to stain clothes.

Setting forth the advantages of the gasoline carriage, Elmer Apperson enumerates the following twelve points: (1) Availability of fuel, readily obtainable anywhere; (2) convenience in renewing the supply, no fire being present that must be extinguished; (3) economy of fuel, owing (*a*) to none being used when the machine is standing, (*b*) to the small amount used when running light, (*c*) to the high efficiency of the gasoline engine —twenty-five or thirty per cent. as against ten per cent. for the steam engine, and less for the electric motor; (4) perfect throttling system for changing the speed and power ratios; (5) noiselessness, as achieved in the later types of motor; (6) ease of using in winter with non-freezing jacket solutions; (7) the absence of indicating devices to distract the mind of the operator; (8) absence of constant fire, as in a steam machine to "make a volcano of the slightest leak"; (9) rareness of total disablement, as against steam or gasoline machines; (10) extended travel radius, gasoline machines having been run 1,000 miles without a stop, as against the record of 100 miles for a steamer, and the average of 30 or 40 miles per charge for the electric; (11) the greater perfection of the gasoline machine, on account of the thought and labor expended in its development; (12) that it can be built with any style of body, for any kind of service, and holds all records for speed and endurance.

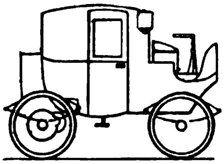
The claims of the electric carriage are set forth by Walter C. Baker under the following twelve heads: (1) The superior material of the electric carriage, together with its durability and attractiveness; (2) the speed range, greater than a horse at low speed and within legal limits at top speed; (3) the small care required in comparison with other types of power, the smallest attention yielding the best results—the battery alone demanding particular care; (4) the ideal source of energy found in the storage battery, which is compact, clean, safe, and able to yield instantly to the will of the operator; (5) freedom from noise, odor or vibration; (6) with all mechanical parts rotating, anti-friction bearings may be used throughout, enabling great results from little power; (7) the slight physical effort required to manage it; (8) absence of oil, fire, water and pumps leaves nothing to freeze, burn, or explode, and requires no pumping at the start; (9) absence of lubricants renders it clean; (10) safety for ladies and convenience for short tours; (11) small number of occasions for failure to run; (12) a single lever to control the motive power, and another for steering, rendering it the simplest of all to manage.

While, strangely enough, all the statements made above are perfectly true and undeniable, it must still be maintained that there is a very real and radical difference in the serviceability of the several types of motor vehicles. Could an electric carriage be constructed with a travel radius per charge of battery of 100 or 150 miles, it would undoubtedly be the ideal type for amateurs on short tours. At present its limited possibilities curtail its usefulness. A steam carriage, equipped with a flash generator and a strongly constructed compact engine is equally useful. But at

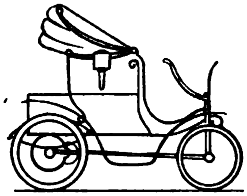


STEAM RUNABOUT.

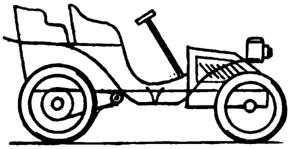
ELECTRIC VICTORIA



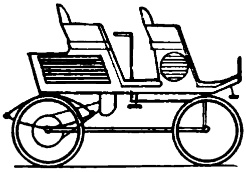
ELECTRIC COUPE.



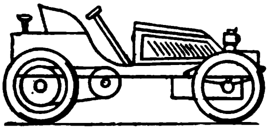
ELECTRIC STANHOPE.



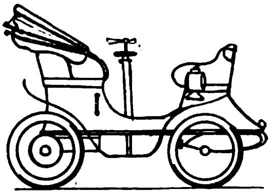
TOURING CAR.



STEAM SURREY.



RACING CAR.



GASOLINE VOITURETTE.

FIGS. 1-8.—Eight Familiar Types of Self-Propelled Road Vehicles.

the present time very many makes of steam carriages fail on account of the bewildering complications which none but close students can fully master. As for the statement that the steam engine is more familiar to the average mind, that must be taken with reservation. A century of discussion and explanation has rendered the steam engine more familiar in its broad and general principles, but the average mind is densely ignorant of its essential details, and completely lost in the presence of the practical problems of operation. In this respect the gasoline engine certainly has the advantage. Its principles once understood, and the few common causes of failure explained, there is little that the amateur needs to know further.

At best, very few people who own and operate motor vehicles care to delve into the mysteries of construction and the mazes of theory. The machine that can be operated with the least care, in return for the greatest service, in horse power, travel compass and speed, is the one that is bound to prevail in the end.

CHAPTER TWO.

A BRIEF HISTORY OF SELF-PROPELLED ROAD VEHICLES.

Requirements for a Successful Motor Carriage.—Even before the days of successful railroad locomotives several inventors had proposed to themselves the problem of a steam-propelled road wagon, and actually made attempts to build machines to embody their designs. In 1769 Nicholas Joseph Cugnot, a captain in the French army, constructed a three-wheeled wagon, having the boiler and engine overhanging, and to be turned with the forward wheel, and propelled by a pair of single-acting cylinders, which worked on ratchets geared to the axle shaft. It was immensely heavy, awkward and unmanageable, but succeeded in making the rather unexpected record of two and a half miles per hour, over the wretched roads of that day, despite the fact that it must stop every few hundred feet to steam up. Later attempts in the same direction introduced several of the essential motor vehicle parts used at the present day, and with commensurately good results. But the really practical road carriage cannot be said to have existed until inventors grasped the idea that the fuel for the engines must be something other than coal, and that, so far as the boilers and driving gears are concerned, the minimum of lightness and compactness must somehow be combined with the maximum of power and speed. This seems a very simple problem, but we must recollect that even the simplest results are often the hardest to attain. Just as the art of printing dates from the invention of an inexpensive method of making paper, so light vehicle motors were first made possible by the successful production of liquid or volatile fuels.

In addition to this, as we shall presently understand, immense contributions to the present successful issue have been made by pneumatic tires, stud steering axles and balance gears, none of which were used in the motor carriages of sixty and eighty years ago. So that, we may confidently insist, although many thoughtless persons still assert that the motor carriage industry is in its infancy, and its results tentative, we have already most of the elements of the perfect machine, and approximations of the remainder. At the present time the problem is not on what machine can do the required work, but which one can do it best.

A Brief Review of Motor Carriage History.—As might be readily surmised, the earliest motor vehicles were those propelled by steam engines, the first attempt, that of Capt. Cugnot, dating, as we have seen, from 1769-70. In the early years of the nineteenth century, and until about 1840-45, a large number of steam carriages and stage coaches were designed and built in England, some of them enjoying considerable success and bringing profit to their owners. At about the close of this period, however, strict laws regarding the reservation of highways to horse-vehicles put an effectual stop to the further progress of an industry that was already well on its way to perfection, and for over forty years little was done, either in Europe or America, beyond improving the type of farm tractors and steam road rollers, with one or two sporadic attempts to introduce self-propelling steam fire engines. During the whole of this period the light steam road carriage existed only as a pet hobby of ambitious inventors, or as a curiosity for exhibition purposes. Curiously enough, while the progress of railroad locomotion was, in the meantime, rapid and brilliant, the re-awakening of the motor carriage idea and industry, about 1885-89, was really the birth of a new science of constructions, very few of the features of former carriages being then adopted. In 1885 Gottlieb Daimler patented his high-speed gas or mineral spirit engine, the parent and prototype of the wide

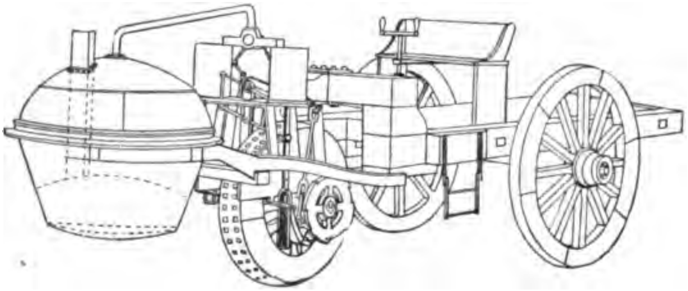


FIG. 9.—Captain Cugnot's Three-wheel Steam Artillery Carriage (1769-70). This cut shows details of the single flue boiler and of the driving connections.

variety of explosive vehicle motors since produced, and, in the same year, Carl Benz, of Mannheim, constructed and patented his first gasoline tricycles. The next period of progress, in the years immediately succeeding, saw the ascendency of French engineers, Peugeot, Panhard, De Dion and Mors, whose names, next to that of Daimler himself, have become commonplaces with all who speak of motor carriages. In 1889 Leon Serpollet, of Paris, invented his famous instantaneous, or "flash," generator, which was, fairly enough, the most potent agent in restoring the steam engine to consideration as means of motor carriage propulsion. Although it has not become the prevailing type of steam generator for this purpose, it did much to turn the attention of engineers to the work of designing high-power, quick-steaming, small-sized boilers, which have been brought to such high efficiency, particularly in the United States. With perfected steam generators came also the various forms of liquid or gas fuel burners. The successful electric carriage dates from a few years later than either of the others, making its appearance as a practical permanency about 1893-94.

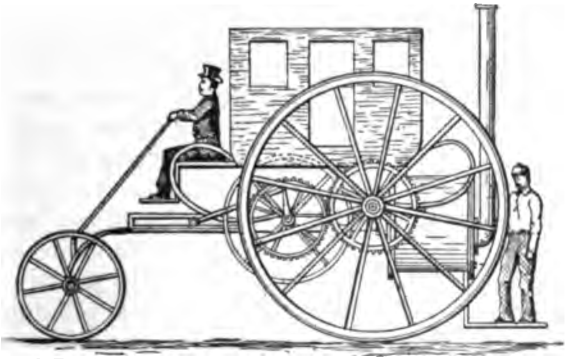


FIG. 10.—Richard Trevithick's Steam Road Carriage (1802). The centre-pivoted front axle is about half the length of the rear axle. The cylinder is fixed in the centre of the boiler. The engine has a fly-wheel and spur gear connections to the drive axle.

Trevithick's Steam Carriage.—In reviewing the history of motor road vehicles we will discover the fact that the attempts which were never more than plans on paper, working models, or downright failures are greatly in excess of the ones even half-way practical. From within a few years after Cugnot's notable attempt and failure, many inventors in England, France and America appeared as sponsors for some kind of a steam road carriage, and as invariably contributed little to the practical solution of the problem. In 1802 Richard Trevithick, an engineer of ability, subsequently active in the work of developing railroad cars and locomotives, built a steam-propelled road carriage, which, if we may judge from the drawings and plans still extant, was altogether unique, both in design and operation. The body was supported fully six feet from the ground, above rear driving wheels of from eight to ten feet in diameter, which, turning loose on the axle trees, were propelled by spur gears secured to the hubs. The cylinder placed in the centre of the boiler turned its crank on the counter-shaft, just forward of the axle, and imparted its motion through a second pair of spur gears, meshing with those attached to the wheel hubs. The steering was by the forward wheels, whose axle was about half the width of the vehicle, and centre-pivoted, so as to be actuated by a hand lever rising in front of the driver's seat. This difference in the length of the two axles was probably a great advantage to positive steering qualities, even in the absence of any kind of compensating device on the drive shaft. The carriage was a failure, however, owing to lack of financial support, as is alleged, and, after a few trial runs about London, was finally dismantled.

Gurney's Coaches.—The Golden Age of steam coaches extended from the early twenties of the nineteenth century for about twenty years. During this period much was done to demonstrate the practicability of steam road carriages, which for a time seemed promising rivals to the budding railroad industry. Considerable capital was invested and a number of carriages were built, which actually carried thousands of passengers over the old stage-coach roads, until adverse legislation set an abrupt period to further extension of the enterprise. Among the names made prominent in these years is that of Goldsworthy Gurney, who, in association with a certain Sir Charles Dance, also an engineer, constructed several coaches, which enjoyed a brief though successful career. His boiler, like those then used in the majority of carriages, was of the water-tube variety, and in many respects closely resembled some of the most successful styles made at the present day. It consisted of two parallel horizontal cylindrical drums, set one above the other in the width of the carriage, surmounted by a third, a separator tube, and connected together by a number of tubes, each shaped like the letter U laid on its side, and also, directly, by several vertical tubes. The fire was applied to the lower sides of the bent tubes, under forced draught, thus creating a circulation, but, on account of the small heating surface, the boiler was largely a failure. Mr. Dance did much to remedy the defects of Gurney's boiler with a water-tube generator, designed by himself, in which the triple rows of parallel U-tubes were replaced by a number of similarly-shaped tubes connected around a common circumference by elbow joints, and surmounted by dry steam tubes, thus affording a much larger heating surface for the fire kindled above the lower sides of the bent tubes. Gurney's engine consisted of two parallel cylinders, fixed in the length of the carriage and operating cranks on the revolving rear axle shaft. The wheels turned loose on the axles, and were driven by double arms extending in both directions

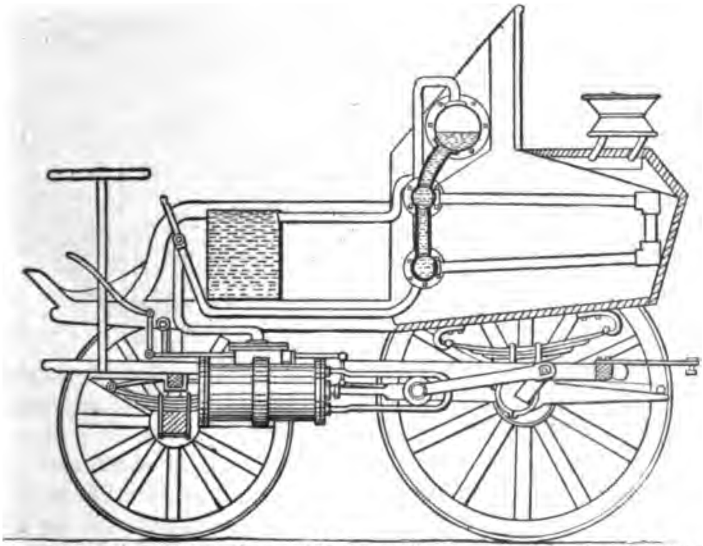


FIG. 11.—Sectional Elevation of one of Goldsworthy Gurney's Early Coaches, showing water tube boiler, directly geared cylinders and peg-rod driving wheel.

from the axle to the felloe of the wheel, where they engaged suitably arranged bolts, or plugs. On level roadways only one wheel was driven, in order to allow of turning, but in ascending hills both were geared to the motor, thus giving full power. In Gurney's later coaches and tractors the steering was by a sector, with its centre on the pivot of the swinging axle shaft and operated by a gear wheel at the end of the revolving steering post. In one of his earliest carriages he attempted the result with an extra wheel forward of the body and the four-wheel running frame, the swinging forward axle being omitted, but this arrangement speedily proving useless, was abandoned.

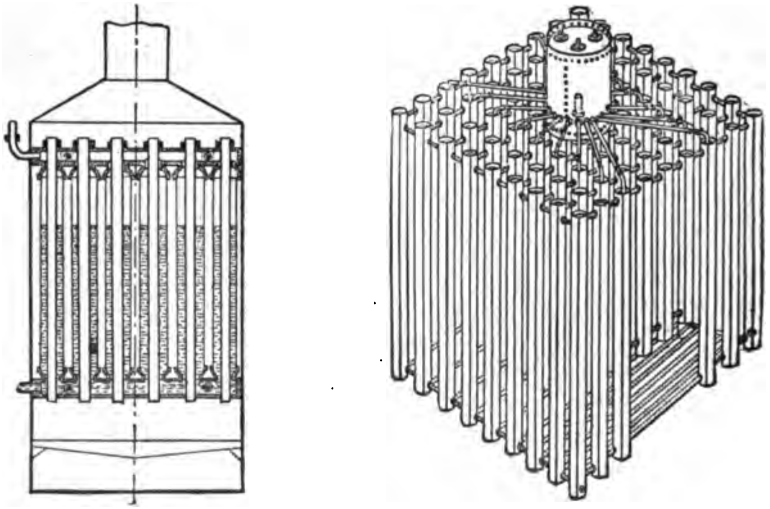


FIG. 12. FIG. 13.

FIGS. 12-13.—Improved Boilers for Gurney Coaches; the first by Summers & Ogle; the second by Maceroni & Squire.

Improvements on Gurney's Coaches.—Several other builders, notably Maceroni and Squire, and Summers and Ogle, adopted the general plans of Gurney's coaches and driving gear, but added improvements of their own in the construction of the boilers and running gear. The former partners used a water-tube boiler consisting of eighty vertical tubes, all but eighteen of which were connected at top and bottom by elbows or stay-tubes, the others being extended so as to communicate with a central vertical steam drum. Summers and Ogle's boiler consisted of thirty combined water tubes and smoke flues, fitting into square plan, flat vertical-axis drums at top and bottom. Into each of these drums—the one for water, the other for steam—the water tubes opened, while through the top and bottom plates, through the length of the water-tubes, ran the contained smoke flues, leading the products of combustion upward from the furnace. The advantage of this construction was that considerable water could be thus heated, under draught, in small tube sections, while the full effect of 250 square feet of heating surface was realized. With both these boilers exceedingly good results were obtained, both in efficiency and in small cost of operation. Indeed, the reasonable cost of running these old-time steam carriages is surprising. It has been stated that Gurney and Dance's coaches required on an average about 4d. (eight cents) per mile for fuel coke, while the coaches built by Maceroni and Squire often averaged as low as 3d. (six cents). The average weight of the eight and ten-passenger coaches was nearly 5,000 pounds, their speed, between ten and thirty miles, and the steam pressure used about 200 pounds.

Hancock's Coaches.—By all odds the most brilliant record among the early builders of steam road carriages is that of Walter Hancock, who, between the years 1828 and 1838, built nine carriages, six of them having seen actual use in the work of carrying passengers. His first effort, a three-wheeled phaeton, was driven by a pair of oscillating cylinders geared direct to the front wheel, and being turned on the frame with it in steering. Having learned by actual experiment the faults of this construction, he adopted the most approved practice of driving on the rear axle, and in his first passenger coach, "The Infant," he attached his oscillating cylinder at the rear of the frame, and transmitted the power by an ordinary flat-link chain to the rotating axle. He was the first to use the chain transmission, now practically universal. As he seems to have been a person who readily learned by experience, he soon saw that the exposure of his engines to dust and other abradents was a great source of wear and disablement; consequently in his second coach, "Infant No. 2," he supplanted the oscillating cylinder hung outside by a slide-valve cylinder and crank disposed within the rear of the coach body above the floor. In this and subsequent carriages he used the chain drive, also operating the boiler feed pump from the cross-head, as in most steam carriages at the present day.

Hancock's boiler was certainly the most interesting feature of his carriages, both in point of original conception and efficiency in steaming. It was composed of a number of flat chambers—"water bags" they were called—laid side by side and intercommunicating with a water drum at the base and steam drum at the top. Each of these chambers was constructed from a flat sheet of metal, hammered into the required shape and flanged along the edges, and, being folded together at the middle point, the two halves were securely riveted together through the flanged edge. The faces of each plate carried regularly disposed hemispherical cavities or bosses, which were in contact when the plates were laid together, thus preserving the distances between them and allowing space for the gases of combustion to pass over an extended heating surface. The high quality of this style of generator may be understood when we learn that, with eleven such chambers or "water bags," 30 x 20 inches x 2 inches in thickness and 89 square feet of heating surface to 6 square feet of grate, one effective horse-power to every five square feet was

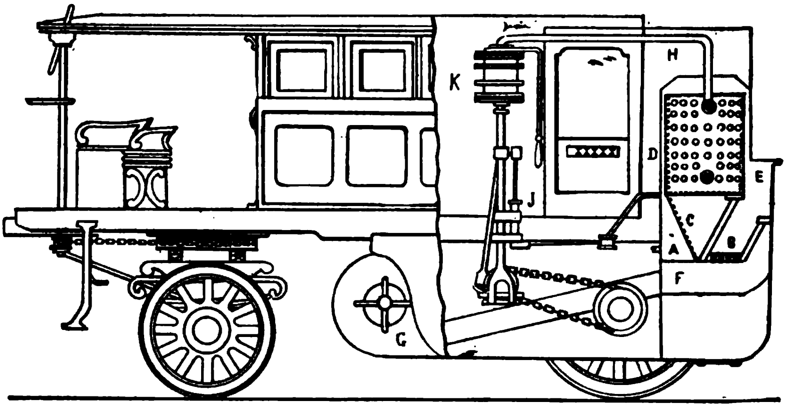


FIG. 14.—Part section of one of Hancock's Coaches, showing Engine and Driving Connections. A is the exhaust pipe leading steam against the screen, C, thence up the flue, D, along with smoke and gases from the grate, B. E is the boiler; H the out-take pipe; K the engine cylinder and, J, the water-feed pump; G is a rotary fan for producing a forced draught, and F the flue leading it to the grate.

realized, which gives us about eighteen effective horse-power for a generator occupying about 11.1 cubic feet of space, or 30 x 20 x 32 inches.

The operation of the Hancock boiler is interesting. The most approved construction was to place the grate slightly to the rear of the boiler's centre, and the fuel, coke, was burnt under forced draught from a rotary fan. The exhaust steam was forced into the space below the boiler, where a good part of it, passing through a finely perforated screen, was transformed into water gas, greatly to the benefit of perfect combustion.

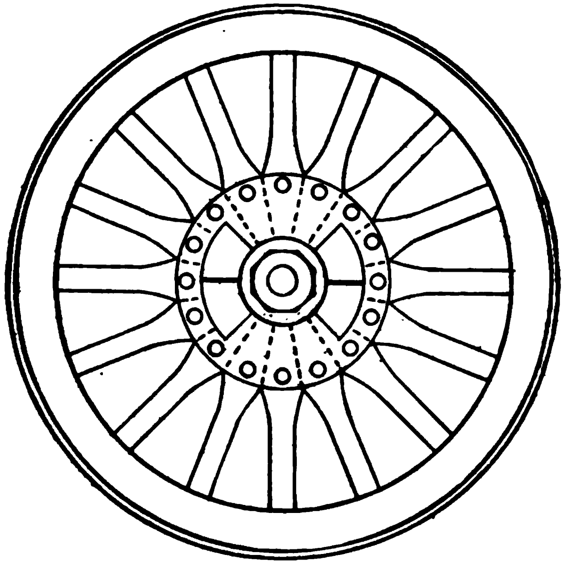


Fig. 15.

Fig 16.

Fig. 15.—Hancock's Wedge Drive Wheel, showing wedge spokes and triangular driving lugs at the nave.
Fig. 16.—One element of the Hancock Boiler, end view.

As early as 1830 Hancock devised the "wedge" wheels, since so widely adopted as models of construction. As shown in the accompanying diagram, his spokes were formed, each with a blunt wedge at its end, tapering on two radii from the nave of the wheel; so that, when laid together, the shape of the complete wheel was found. The blunt ends of these juxtaposed wedges rested upon the periphery of the axle box, which carried a flange, or vertical disk, forged in one piece with it, so as to rest on the inside face of the wheel. This flange was pierced at intervals to hold bolts, each penetrating one of the spokes, and forming the "hub" with a plate of corresponding diameter nutted upon the outer face of the wheel. The through axle shaft, formed in one piece and rotatable, carried secured to its extremities, when the wheel was set in place, two triangular lugs, oppositely disposed and formed on radii from the nave. The outer hub-plate carried similarly shaped and disposed lugs, and the driving was effected by the former pair, turning with the axle spindle, engaging the latter pair, thus combining the advantages of a loose-turning wheel and a rotating axle. Through nearly half of a revolution also the wheel was free to act as a pivot in turning the wagon, thus obtaining the same effect as with Gurney's arm and pin drive wheels. The prime advantage, however, was that the torsional strain was evenly distributed through the entire structure by virtue of the contact of the spoke extremities.

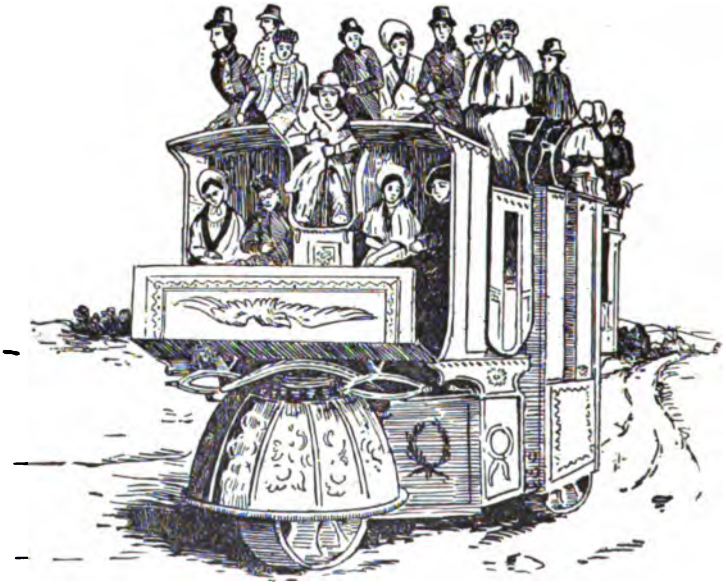


FIG. 17.—Church's Three-wheel Coach (1833), drawn from an old woodcut, showing forward spring wheel mounted on the steering pivot.

Other Notable Coaches.—According to several authorities, only Gurney, Hancock and J. Scott Russell built coaches that saw even short service as paying passenger conveyances—one of the latter's coaches was operated occasionally until about 1857. There were, however, numerous attempts and experimental structures, all more or less successful, which deserve passing mention as embodying some one or another feature that has become a permanence in motor road carriages or devices suggestive of such features. A coach built by a man named James, about 1829, was the first on record to embody a really mechanical device for allowing differential action of the rear, or driving, wheels. Instead of driving on but one wheel, as did Gurney, or using clutches, like some others, he used separate axles and four cylinders, two for each wheel, thus permitting them to be driven at different speeds. This one feature entitles his coach to description as the "first really practical steam carriage built." Most of the others, if the extant details are at all correct, must have been, except on straight roads, exceedingly unsatisfactory machines at best. According to the best information on the subject, a certain Hills, of Deptford, was the first to design and use on a carriage, in 1843, the compensating balance gear, or "jack in the box," as it was then called, which has since come into universal use on motor vehicles of all descriptions. As for rubber tires, although a certain Thompson is credited with devising some sort of inflatable device of this description about 1840-45, there seems to have

FIG. 18.—James' Coach (1829), the "first really practical steam carriage built." Drawn from an old wood cut.

been little done in the way of providing a springy, or resilient, support for the wheels. We have, however, some suggestion of an attempt at spring wheels on Church's coach, which was built in 1833. According to an article in the *Mechanics' Magazine* for January, 1834, which gives the view of this conveyance, herewith reproduced, "The spokes of the wheels are so constructed as to operate like springs to the whole machine—that is, to give and take according to the inequalities of the road." In other respects the vehicle seems to have been fully up to the times, but, judging from its size and passenger capacity, as shown in the cut, it is reasonable to suppose that the use of spring wheels was no superfluous ornamentation. If we may judge further from the cut, the wheels had very broad tires, thus furnishing another element in the direction of easy riding on rough roads.

CHAPTER THREE.

HOW A MOTOR CARRIAGE TURNS.

Modern Motor Vehicles. — Like other achievements of modern science and industry, the motor vehicle is the resultant of a long series of brilliant inventions and improvements in several directions. Successful motor carriages, as now constructed, are of three varieties, according to the motive power employed: those propelled by steam; those propelled by explosive motors, gas or oil engines; those propelled by electricity. Considerable has also been done in the direction of producing efficient compressed air motors, which have been actually applied to the propulsion of heavy road wagons and street railway cars, but for light carriage service small results have thus far been attained. Some inventors have expended their energies in other directions, and several patents have been granted in the United States for coiled spring and clockwork motors, and even for carriages carrying masts and sails. We are not concerned, however, with such eccentric devices; the aim of this book being merely the discussion and explanation of successful, practical methods actually applied in the construction and operation of light motor carriages.

Conditions of Automobile Construction.—In one way the automobile has a history very like that of the railway carriage. At the first inception both were devised as suitable substitutes for the horse-drawn vehicle, and, as a consequence, began by following certain traditions of construction, which have proved very like hindrances to progress. The first railway passenger coaches were no more nor less than ordinary road wagons, several being coupled together, so as to be drawn along a grooved tramway. Later, with the introduction of flanged wheels and heavier constructions, a number of carriage bodies were mounted on the same running trucks, which gave the familiar compartment coaches with *vis-a-vis* seats, still used in England and most of the countries of Continental Europe. Only when the theory of railway car construction departed entirely from the models and traditions of road wagons in the invention and adoption of the American passenger coach, did the day of real progress and comfortable travel begin. In similar fashion, it may be safely asserted, many of the greatest constructional problems of automobiles are to be traced to the tradition of building motor carriages as nearly like horse-drawn vehicles as possible. It seems that the most popular designs of such vehicles are those which appear to be horse-carriages in all respects except that they lack the ordinary shafts or poles for hitching the horses. These structural problems are, however, real problems, and with both railway coaches and automobiles the adoption of traditional models has been only the following of the best available designs.

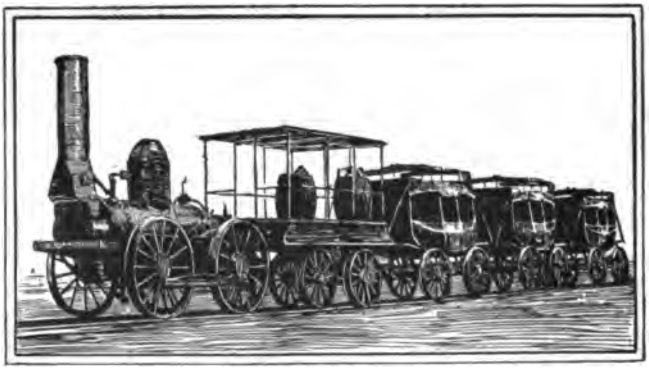


Fig. 19.—Early American Railroad Train (1834), showing passenger coaches, which are simply transformed road stages.

Problems in Automobile Construction.— In a horse-drawn vehicle the tractive power, the harnessed horse, is applied at the front and is separate from the carriage or wagon itself. Therefore, the only thing needful is to so construct the frame and running gear as to offer the smallest resistance either in straight-ahead travel or turning. As is well known, each running wheel of a horse carriage is made with a pierced hub and hollow axle box or bearing, so as to be slipped over the end of the axle-bar and secured in place by a nut. The axle-bar of the rear wheels is continuous and rigid with the frame, being attached to the springs supporting the body. The axle-bar of the forward wheels is also continuous from side to side, but, instead of being bolted to the rest of the frame, is geared to a structure commonly called the "fifth wheel," a horizontal flat wheel or "circle iron," secured to the base of the forward spring, and sliding on another similar segment on the top of the axletree; the two being pivot-bolted at the centre, so as to allow the forward wheels to "cut under" the vehicle, and turn the wagon on any radius its length and weight will permit. Were it practicable in all cases to apply the motive power to the pivoted-axle forward wheels, this same plan of construction would be as good for automobiles as for horse carriages.

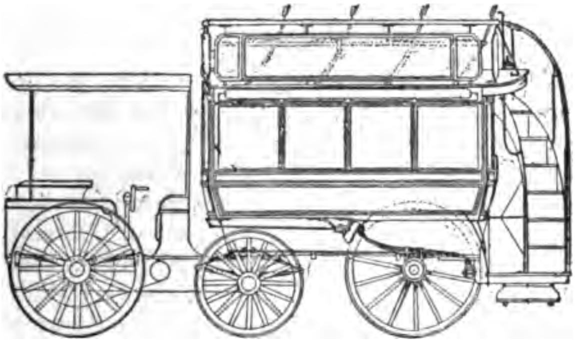


FIG. 20.—A Mechanical Horse—the Carmont Tractor—Intended to be attached to any form of horse-drawn vehicle at the turn-table, or "fifth wheel." It is steered by its rear wheels and drives on the forward pair.

But such a thing is impossible unless we employ either a separate motor truck—a mechanical horse, in fact—or some yet undiscovered method of power-transmission gear. This is the first constructional problem, and a moment's serious reflection will reveal the involved difficulties.

Imitations of Horse Traction. — Curiously enough, in the very first road locomotive ever made—that of Nicholas Cugnot—a desperate attempt was made to meet and solve the difficulty of combining power-traction with free turning attachments. As we have learned, Captain Cugnot employed a single pivoted forward wheel, which was geared rigid to one frame with his engine and boiler, the whole motor-structure turning with every effort to steer the wagon around a corner. He saw readily enough that to attach the boiler to the frame of the carriage would involve the difficulties and complications incident on telescopic, or extensile, steam connections between boiler and engine, which would, likely, have caused serious trouble. He adopted, therefore, the readiest expedient. His wagon worked very well on a straight road, but developed the disagreeable qualities of "ending up" at every corner, and of refusing to "obey its helm" whenever a stone wall, or other obstruction, made a collision convenient. Had he slung his boiler at the rear of the forward wheel, on the floor of the wagon, he might have overcome the tendency to "top-heaviness" and solved the problem of motor road traction a century sooner.

Present-Day Construction. — Practically all present-day motor carriages have the power applied to the rear wheels, doing the steering with the forward pair. This plan, of course, involves several serious problems, the foremost of which is as to how a carriage can turn a corner, long or short, with both wheels moving at the same rate of speed. If anyone will observe the rear wheels of a carriage in the act of turning, he will see that the one, the pivot wheel, does not revolve or revolves very slowly, as the radius of the described arc be shorter or longer; while the other wheel carries the vehicle around with it. Now, if the power is to be applied to the wheels, either by chain and sprocket, by spur gears or by a crank, either one of six devices must be adopted: (1) The power may be applied equally to both wheels, as in railway locomotives, in which case only turns of very long radius could be made. This is the reason why the curves of railroads are seldom made on a radius of less than three-eighths of a mile (1,980 feet), although, since the steel rails offer immensely less resistance to the wheels than an ordinary road bed, often allowing the drivers to revolve without progressing, there is much smaller need of devices for equalizing or compensating the motions of the pairs. If, then, an automobile can always have a ten-acre lot or a 200-foot road to turn in, it may be able to drive on the locomotive plan: under ordinary conditions it must speedily smash something and come to grief. (2) The motive power may be applied to one wheel of a pair and not to the other, either or both turning loose on the axles. But such a plan would not only give the carriage a constant tendency to "lurch," rendering forward movement exceedingly difficult, but it would allow turning in only one direction, except on extremely long curves. (3) There may be two separate motors, one for each wheel, both capable of being controlled with the steering apparatus. Such a plan has been put into actual practice by several manufacturers of electrical vehicles, who gear their motors to the wheels, or use the hub to support either the armature or field magnets, as the case may be. One maker of American steam carriages has adopted a similar construction, connecting several small cylinders

Fig. 21.—Bergman's Steam Motor Wheel. A number of steam cylinders are arranged within the hollow hub of the wheel, so as to act on a common crank on the axle. The action is on the plan of a compound engine, the steam being exhausted at low pressure.

direct to each wheel hub. The plan has its advantages, but is by no means as simple, accessible and sightly as using one motor with sprocket connections to the centre of the rear driving shaft. (4) The driving wheels may be attached to the rotating axle by clutches, which may be "thrown out" by geared connections to the steering mechanism. To be really practical the act of disengaging must be effected by the steering lever, otherwise the driver might forget it at the very time it was needed most. The disadvantage of the arrangement is thus obvious; for, since a considerable motion of the lever is required to release the clutch, the device would be of use only on short curves, as in turning street corners, when the lever is put all the way about. On long curves there could be no certainty that disengagement had been effected, unless complex devices and long connections were employed, greatly to the detriment of an easy operation of the steering lever. With the best arranged mechanism there must be some stress and strain on the drive wheels, in consequence of attempting by hand what should be accomplished automatically. Also, if the clutch is to be thrown out every time the steering wheels incline, ever so slightly, the driving must be irregular, and the speed consequently impaired. (5) The hub of each wheel may be provided with a ratchet arrangement, adapted to engage the axle and prevent it from rotating forward without engaging the wheel. Such a construction was used on foot-propelled tricycles twenty years ago, but was then found faulty because, in turning corners, the inner wheel had to do the driving. Since that time several improved designs have been made that allow of working in a reverse direction, the pawl being so hung as to shift by slight friction contact, so that, if the axle rotates forward, it will drive the wheel forward, and also the contrary. With all produced to date, however, the same fault has been found: When attempting a slight hill, there is no way of controlling the vehicle except by applying the brake until the power is reversed and the pawls can take a positive grip. Altogether, the best pawl and ratchet devices are uncertain and unsatisfactory in action and also seem unmechanical and unsuitable for motor vehicle use. (6) The construction most usually adopted is to attach both drive-wheels rigidly to a revolving axle bar, which is divided at the centre to connect with a system of *compensating* or *balance* gear wheels enclosed within a cylindrical case carrying the sprocket. Here there is no loss of power; no need of lowering the speed on curves of safe radius, and no necessity for complicated and troublesome devices for coupling the motive and steering functions.

The Requirements in Balance Gears.—The balance or compensating device, as used on motor vehicles, is commonly called a "differential gear," from the fact that the primary object involved in its use is, as we have seen, to allow of differentiation or compensation in the speeds of the two geared wheels and their axles in making curves. Any device that will admit of a steady drive in straight-ahead running, a difference of speed in the two drive-wheels in turning corners, and a rapid restoration of normal conditions, is usable for this purpose. There is, however, another necessary function, which may not be omitted—the differential must also be a "balance gear." That is to say, it must combine with the function of compensation an even or balanced transmission of power to both wheels. Each wheel, so long as it is in motion, must be driven with the same degree of power.

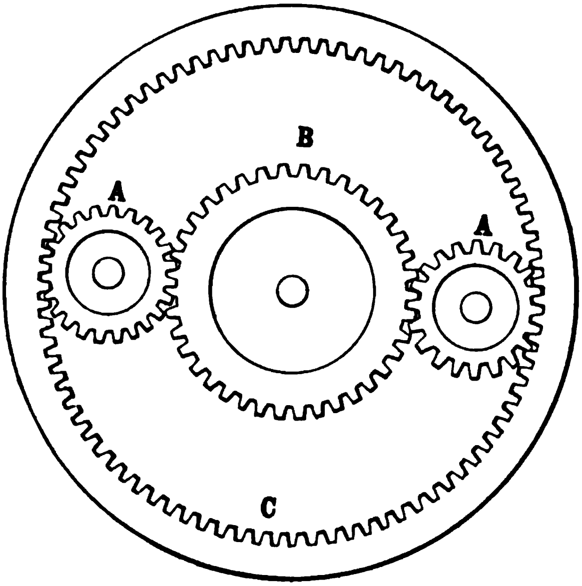


FIG. 22.—A form of Differential Gear formerly used on Tricycles. The studs of the pinions, AA, are set in spokes of the sprocket, turning on their own axes only when either of the wheels of the vehicle, attached respectively to B and C, cease rotating, as in the act of turning.

At no time, even on short turns when one wheel is stationary, acting as a pivot, is it permissible that, say two-thirds of the power, be sent to one drive-gear, and one-third to the other. The power, transmitted from the centre of the divided axle shaft, must always be the same in both directions, even though one wheel be stationary. On some driven vehicles, particuarly two-track foot-propelled tricycles, in which the steering wheel is set directly ahead of one of the drivers, so as to progress on the same track, it is desirable to use a compensating gear that is not a balance gear, because more power is required on one side than on the other. The failure to understand this fact in the early days of cycling led to considerable uncertainty in the steering of tricycles. One of these early machines, a three-track tricycle—one having the steer wheel hung forward the centre of the two drivers—had the compensating device shown in an accompanying figure, instead of the true balance gearing it should have had. The device shown would have answered excellently well in a two-track tricycle, for the reasons noted above. As may be seen, the device consisted of a large internal gear wheel, within which and rotating about the same axis was a smaller external gear or spur wheel—the two meshing with the spur pinions at top and bottom, as shown. The large internal gear was secured to the axle of one wheel, the smaller or spur wheel to the opposite one, and power was applied through the pinions hung on the sprocket. The result was that the power-driven pinion transmitted more power to the internal gear, because of its greater diameter, than to the spur gear, thus giving one wheel a tendency to revolve more rapidly than the other.

Automobile Gears.—The most familiar form of balance gears for compensating the drive wheels of motor carriages is the bevel, or miter, gear train. This is the original form of the device, and was used on steam road wagons as early as 1843. As shown in the figure, the sprocket or spur drive wheel has secured to its inner rim several studs carrying bevel pinions, which, in turn, engage a bevel gear wheel on either side of the sprocket. These gear wheels, last mentioned, are rigidly attached on either side to the inner ends of the centre divided axle-bar, one serving to turn the left wheel, the other, the right. When, now, power is applied to the sprocket, causing the vehicle to move straight forward, it may be readily understood that the bevel pinions, secured to the sprocket, instead of rotating, which would mean to turn the drive wheels in opposite directions, remain motionless, acting simply as a kind of lock or clutch to secure uniform and continuous rotation of both wheels. So soon as a movement to turn the vehicle is made, causing the wheels to move with different speeds, a fact already mentioned in connection with horse-drawn carriages, these pinions begin to rotate on their own axes, allowing the pivot wheel to slow up or remain stationary, as conditions may require, while still continuing to urge forward the other at the indicated speed. The principle involved in the device may be readily expressed under four heads: (1) When the resistance offered by the two drive wheels and attached gear is the same as when the carriage is driven forward, the pinions cannot rotate. (2) When the resistance is greater on the one wheel than on the other, they will rotate correspondingly, although still moving forward with the wheel offering the lesser resistance. (3) The pinions may rotate independently on one gear wheel, while still acting as a clutch on the other, sufficient in power to carry it forward. (4) If a resistance be met of sufficient power to stop the rotation of both wheels and their axles, the condition would affect the entire mechanism, and the pinions would still remain stationary on their own axes, just as when in the act of transmitting an equal movement to both wheels.

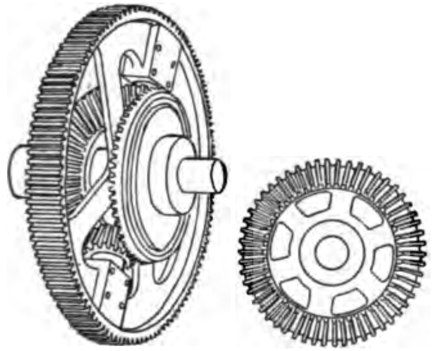


FIG. 23.

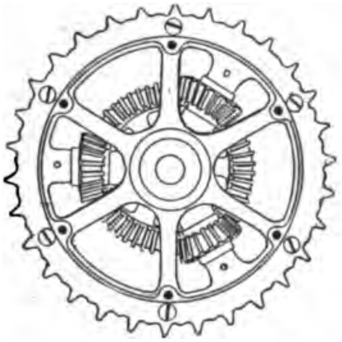


FIG. 24.

FIGS. 23 and 24.—Bevel Gear Differentials. The sprocket gear carries three bevel pinions set on studs on three of its radii. These pinions mesh with bevel wheels on either side, which wheels are attached at the two inner ends of the divided axle shaft. The spur drive has two pinions rotating on radii, and shows the action to better advantage.

For light carriage work the sprocket or spur drive generally carries two pinions, as shown in the figure, but in larger vehicles the number is increased to three, four, or six, and the size, pitch and number of the teeth varied, according to requirements. Of course, it is essential that the equalizing gears be properly chosen for the work they are to perform, in the matter of the number of the pinions and of their teeth, as well as of the metal used, since the great strain brought to bear on them will inevitably cause wear and strain. With even the best made bevel-gears there is a danger of end thrust and a tendency to crowd the pinions against the collars, with consequently excessive wear on both. The result is a looseness that demands constant adjustment.

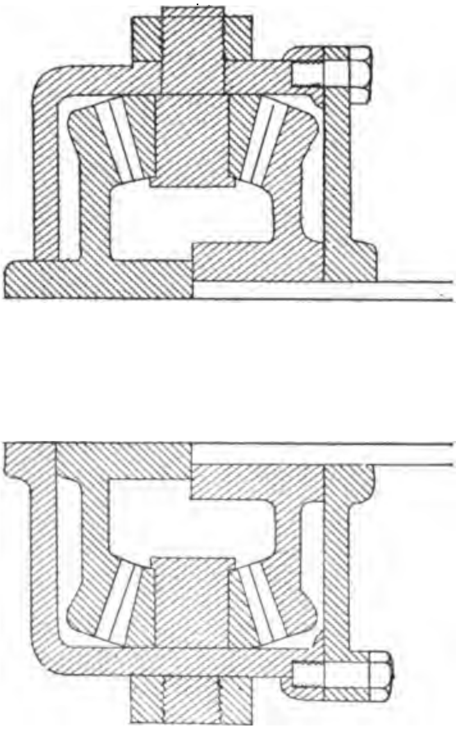


FIG. 25.—Section through the axis of a bevel gear differential train, showing two bevel pinions attached at top and bottom of the sprocket drum, and two bevel gear wheels one on the through axle shaft, the other on a rotating sleeve.

Spur Compensating Gears.—In order to avoid the difficulties encountered with bevel gears, spur-gears were invented, and are now increasing in popularity. In this variety the theory of compensation is the same as with bevel gearing; a divided axle, whose two inner ends carry gear wheels cut to mesh with pinions attached to the sprocket pulley. These pinions are, however, set in geared pairs, with their axes at right angles to the radius of the sprocket, which is to say parallel to its axis. As will be seen in the accompanying illustrations, the pinions of each pair are set alternately on the one side or the other of the sprocket, meshing with one another in about half of their length, the remainder of each being left free to mesh with the axle spurs on the one or other side. Both these models have three pairs of pinions, one of each meshing with either of the axle gears. With one the ends of the divided axle carry internal gears, with the other true spur-wheels. The operation is obvious. When the vehicle is turning, one rear wheel moves less rapidly, causing the pinion with which it is geared to revolve on its mate, which, in turn, revolves on its own axis, although still engaging the gear of the opposite and moving wheel of the vehicle. The motion is thus perfectly compensated, without the wear and thrust inevitable with bevels.

FIG. 26.—One form of Spur Differential or Balance Gear. The two inner ends of the divided axle shaft carry spur wheels, which mesh each with one of every pair of the the three pairs of open pinions shown. As these pinions mesh together both rotate on their axes as soon as turning of the wagon begins.

A Universal Joint Differential.—Another differential device, which has been used on some European vehicles, and was formerly patented in the United States, is shown in the accompanying figure. In this, as in other forms of differential gearing, the axle shaft is divided at the centre, but instead of rigidly attached gears, carries a universal joint on each inner end, on which is a short shaft and a small spur pinion. Over the divided axle shaft are two hollow sleeves, which work freely over it, and are connected together by a gear box, as shown. Within this gear box the two ends of the wheel axle shafts are arranged in bearings at an angle of about thirty degrees, so that the pinions can mesh. The driving is done by a sprocket attached to the outer hollow shaft just mentioned, and the motion is transmitted to the inner shafts attached to the vehicle wheels on either side by the differential gearing; the spur pinions, in this as in the former cases, locking fast without rotating so long as the motion of the wheels is equal and the carriage is driven straight ahead. As soon as a turn is made the pinions begin to rotate with the compensating effect found in the bevel and spur gear trains noticed above.

FIG. 27.—Another form of Spur Balance Gear. The action is the same as in Fig. 26, except that the inner ends of the divided axle carry internal gear wheels, each of which meshes with one pinion of each pair.

A rather simpler variation of this device has been proposed, although not widely used, which consists of two gears slightly beveled, one mounted direct on the straight axle shaft, the other, on a universal joint, as shown. By this construction one universal joint is saved, while the compensating action of the device is not at all impaired.

Disadvantages of a Divided Axle Shaft.—The practice of dividing the axle shaft, thus disconnecting the two wheels of the vehicle, is a source of weakness which was recognized and provided against long since. Although, theoretically, the axle is divided at the centre, as we have described, the construction now usually adopted is to mount one wheel on the axle shaft and the other on a hollow shaft or sleeve which works over it. The solid shaft can then be made as long as the width of the vehicle, the differential gear wheel belonging to it being secured about midway in its length. The other or hollow shaft is about half as long, so that its gear is attached at the end and is immediately opposite the other, both meshing with the pinions attached to the sprocket. Such a construction involves no other variation from the method of attaching the differential gear-train to the ends of the divided axle than making the eyes of the two gear wheels of different diameters, so as to fit the axle shaft, on the one side, and, the hollow axle, or sleeve, on the other. The sprocket is then inserted between them, being held in position by the meshing of the axle gears with the pinions, itself turning loose on the solid through shaft. The inner, solid axle shaft is secured in position by suitable collars. The arrangement may be understood by reference to Fig. 25.

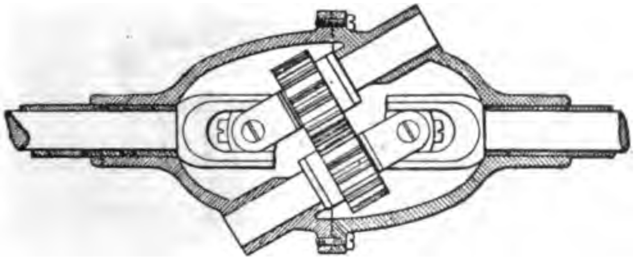


FIG. 28.—A Universal Joint Differential. The sprocket or spur drive turns the sleeve which holds the gear case here shown in section. So long as travel is straight ahead neither pinion rotates on its axis, but as soon as a turn is made rotation begins, thus allowing compensation of the motion of the two wheels of the wagon.

Another Through Axle Shaft.—Another typical method for securing the strength and solidity of a through axle shaft is to attach both wheels to hollow axles of the same diameter, each of which carries on its opposite, or inner, end the gear wheel of the differential train. Another tube, called the "liner tube," of the same length as the width of the vehicle, is then inserted in the hollow axles, and the two are brought together so as to bear upon a collar secured to the centre of the liner tube. The sprocket and differential pinion train are inserted and held in place in a fashion similar to that used in the previous device, the inter-meshing of the bevels serving to support it.

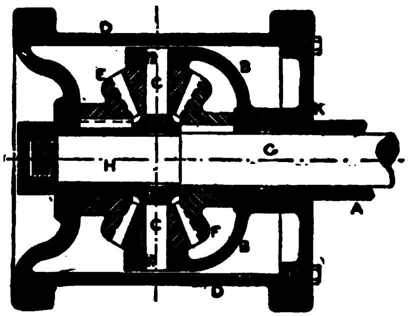


FIG. 29.—The Hub-Enclosed Differential of the Riker Carriages. A is the rotating sleeve carrying the drive spur. It is bolted to the yoke carrier, B, and the flange piece, K, as shown. C and C are the studs of the bevel pinions attached to the yoke carrier, B. F is the bevel gear wheel keyed to the rotating through axle shaft, G, whose opposite end is rigidly attached to the other hub. The bevel gear, E, is keyed to the in-flanged portion of the hub, D, turning on the reduced portion, H, of the rotating axle shaft.

A Hub-Enclosed Differential.— The problem of how to secure compensation of motion between the two rear wheels, and at the same time overcome the disadvantages of the divided axle shaft is solved in a different fashion by the Riker Electric Vehicle Co. Their device is, briefly, to construct the wheels with box hubs and to enclose the differential gear-train in one of them. By this means the carriage frame enjoys the full advantage of a solid through axle shaft, and the divided connection is made at one end instead of at the centre. The mechanism is as follows: A solid through axle shaft is rigidly attached to the hub of one wheel, and has the opposite one running loosely upon it, secured by nut and washer, as in the construction used for horse-drawn vehicles; howbeit, the gearing within the hub prevents its ready removal by unscrewing the nut. Over the solid through axle shaft, which rotates with the wheel attached to it, is sleeved a hollow rotating shaft, which carries the drive sprocket or spur. One end of this second shaft works on a bearing with the drive gear wheel, the other carries a hemispherical yoke-carrier to which are studded differential bevel pinions having their axes on the radii of the shaft. To the rear of this yoke piece is a circular flange piece of a size to fit the inner circumference of the box hub, and turn loosely, when the differential gearing is brought into action: when the drive is straight ahead it turns with the hub, being of one piece with the yoke carrying the bevel pinions. The differential train is completed by the addition of the two side gear wheels, meshing with the bevel pinions, as in other systems of compensating mechanism. One of these gear wheels, the inner

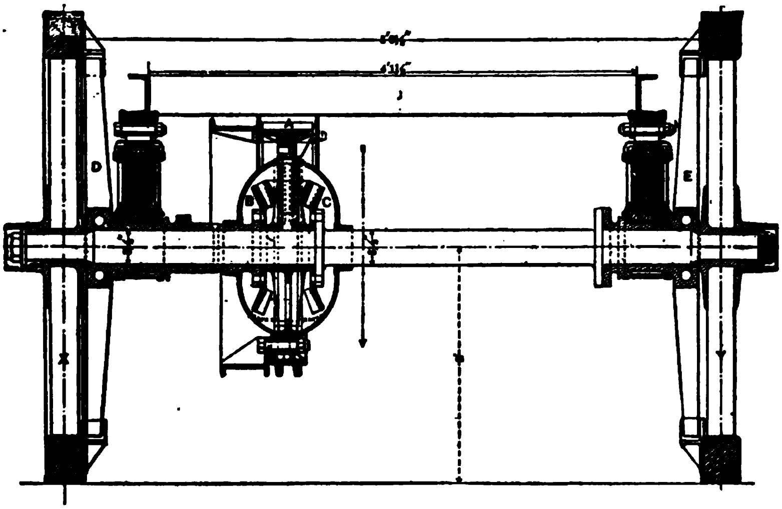


FIG. 30.—The rear axle of the Thornycroft steam wagon, showing the peculiar arrangement of the differential gears and driving connections. The driving is by the spur gear, A, attached on the gear box in the usual manner. The bevel gear, C, is mounted rigidly on the right side of the solid through-axle shaft. The gear, B, is similarly mounted on a sleeve at the left. The wheels, X and Y, turn loose on the through rotating axle, being driven by the springs, D and E, which bear upon lugs at the rim, as will be subsequently explained. This arrangement permits the removal of either wheel, as in horse carriages. G and F are the wagon springs, one resting above the rotating axle, the other above the rotating sleeve.

one, is keyed to the solid through axle shaft, and turns or stops, according to the motions of the opposite wheel of the vehicle. The other is keyed to an in-flanged sleeve on the hub, this sleeve working loose on the extremity of the solid axle shaft, which is turned to a smaller diameter than the remainder of the length, and is terminated by a nut and washer, as previously mentioned.

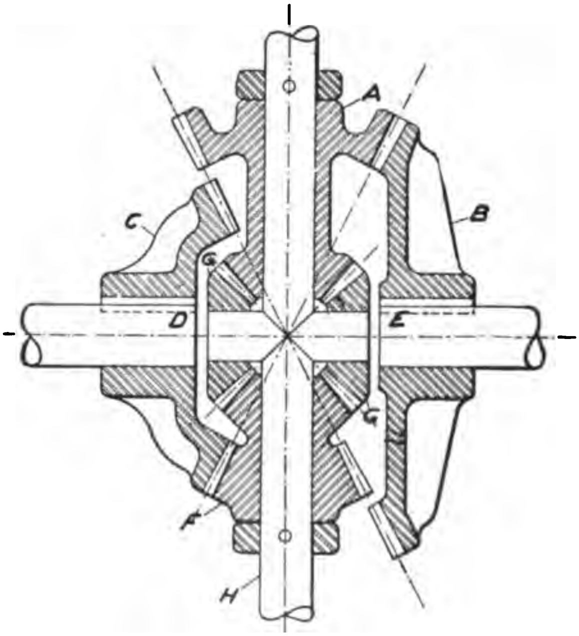


FIG. 30a.—Plan view of a type of differential and transmission gear for permitting the use of dished wheels. H is the driving shaft, which drives the bevels, B and C, on the two half axles, D and E, through the bevels, A and F. These last are loose on H, being held rigid by intermeshing with pinions, G, G, carried on a cross arm on H. Differential action between the two rear wheels is obtained when, in turning, B or C offers resistance to the rotation of A or F; such resistance causing the pinions, G and G, to rotate on their axes, compensating the movements of the two wheels, as in other differential gears. This device allows the use of dished wheels, since, as is evident, the gears, B and C, may be inclined at any desired angle together with their axles, by merely altering the angles of the bevels. The ratios of the gears, B and A, and C and F, being the same the balance of speed and power in transmission is maintained.

The differential action is obvious, since the bevel pinions are studded to a yoke-carrier at the end of the hollow drive-shaft, instead of to the sprocket or driving spur; one bevel-gear of the train being secured to the axle solid with the wheel opposite to the differential hub, and the other to the body of the differential hub itself.

CHAPTER FOUR.

STEERING A MOTOR CARRIAGE.

Steering Gear of Automobiles.— In a horse-drawn vehicle, as we have seen, the front axle shaft is centre-pivoted below the body of the carriage and in turning bears on the "fifth wheel." Such an arrangement is the most practical for this class of vehicle, since the tractive power, the horse, can pull in any direction without the use of further appliances than the guiding lines, or reins. In motor vehicles, however, it is not always practicable to so combine the steering and tractive functions, as to imitate the actions of a horse. Consequently, it is necessary to provide mechanical means for shifting the direction of the forward or steering wheels. This result may be accomplished by attaching some kind of lever, sprocket, or spur-gear arrangement to a "fifth wheel," and operate it by a handle near the seat of the carriage. To successfully accomplish this result with a steering handle, such as is used on most American motor carriages, would require a considerable expenditure of muscular energy and a wide angle of leverage, besides involving delay and difficulty on many turns. With a well-geared steering wheel it has been successfully adopted by Panhard and Levassor, in one of their light two-seated cars. For general purposes, however, the simplest and readiest construction

Fig. 31.—Panhard-Levassor Light Two-Passenger Car, having a Swinging Front Axle. The steer wheel pillar carries an arm on its end to which is attached a link bar working a similar arm on the pivot of the axle, as shown.

for attaining easy steering, and at the same time securing the needed stability of the frame, is found in the use of a rigid through axle shaft and knuckle-jointed stud axles.

Pivoted Stud Axles.—In automobiles the forward axle shaft is attached beneath the body of the vehicle, so as to admit of no rotary movement whatever on its own centre. At each end it carries a fork, or yoke, to which is pivot-bolted, at right angles to the axle shaft, so as to form a true knuckle-joint, a boss carrying two branches, one of them of cylindrical shape to fit the axle box of the wheel, which is suitably secured, as in horse-drawn vehicles, so as to rotate freely; the other being an arm, shaped for attaching the transverse steering link bar. This link bar is generally arranged to connect the steering arms of both stud axles on the through axle shaft, the connections for the control handle or wheel, placed conveniently to the driver's hand, varying with different manufacturers. Pivoted axles, which are generally known as the Ackerman axles, and were invented by a certain Lankensperger of Munich, as early as 1819, thus furnish the readiest and simplest means for steering motor vehicles, at the same time permitting maintenance of stability. The transverse

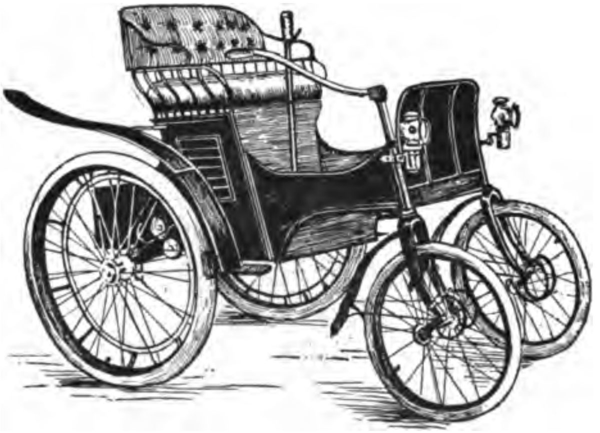
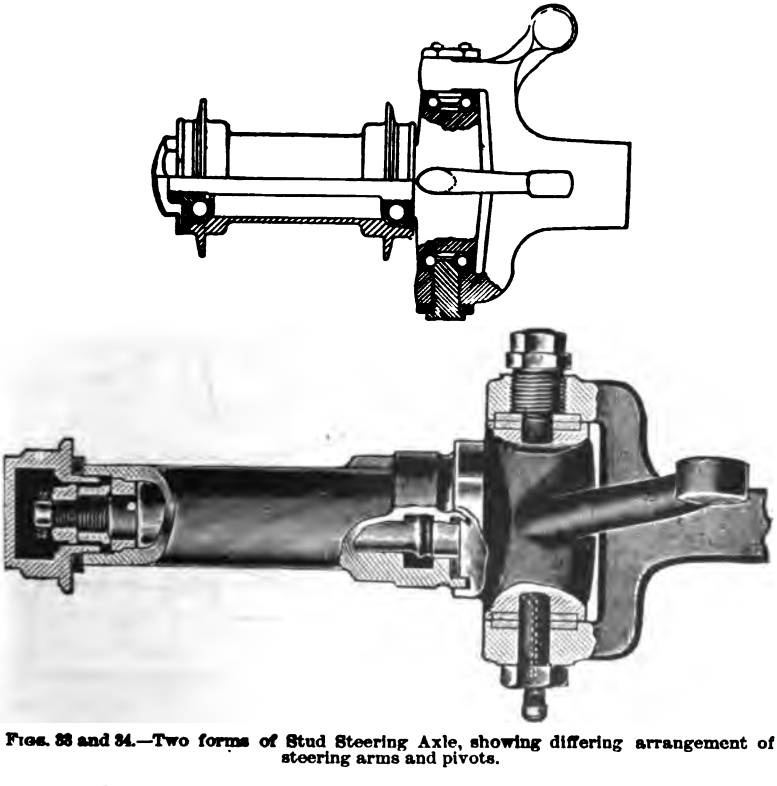


FIG. 32.—The Oakman-Hertel Gasoline Carriage, showing the steer wheels set in and turned by bicycle forks.

steering link bar attached to an arm at either end is readily manipulated by the driver, and with but small exertion, since the pivots, attached direct to the axles of the wheels, permit a wide angle of variation in the vehicle's direction of travel for a very slight shifting of the steering handle. The balance of leverage being also in the driver's favor, it is possible to turn the vehicle in any desired direction quickly and with ease. This same fact also involves that the steering handle cannot be wobbled or vibrated.



Figs. 33 and 34.—Two forms of Stud Steering Axle, showing differing arrangement of steering arms and pivots.

The Theory of Steering Axles. — The operation of pivoted steering axles depends upon fixing the pivot as near as possible to the centre of the wheel, in order to enable the greatest arc of operation for the smallest motion of the hand lever. In this respect the steering wheel of a bicycle is typical, and some makers of automobiles who use steering wheels similarly mounted on forks, either in pairs, as in the Oakman gasoline carriage, or as a single front wheel, as in the Knox three-wheel gasoline carriage, are able thus to secure a remarkably easy and efficient leverage. But, since this construction is not the most suitable for heavy carriages, and is not generally popular, manufacturers and inventors have busied themselves devising other methods for accomplishing the same result. One of these is to incline the stud axle downward at such an angle as will cause the tire, or periphery, of the wheel to strike the ground at a point coincident with a line drawn through the knuckle pivot. As an additional ad-

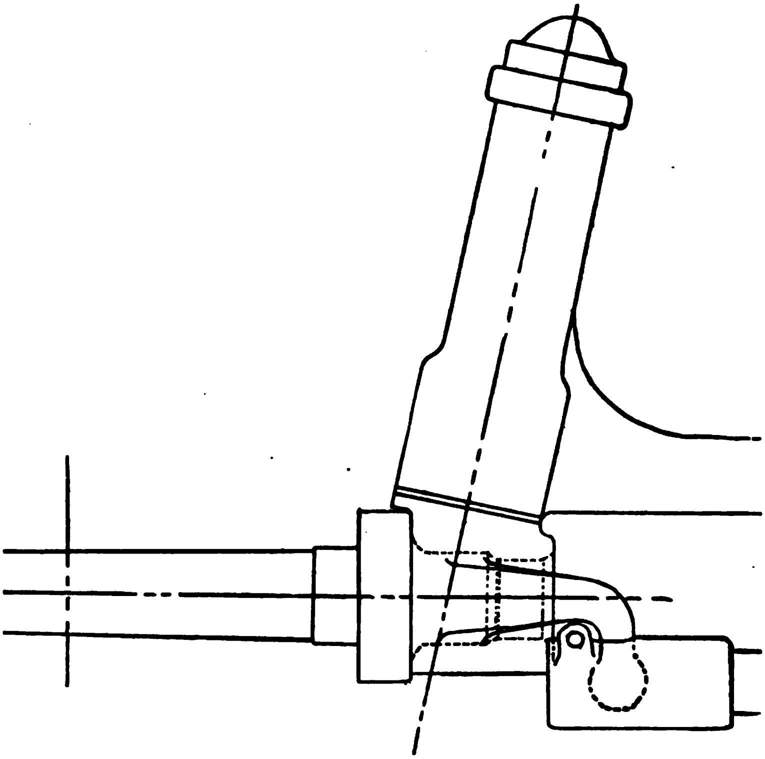


FIG. 35.—Inwardly Inclined Steering Pivot of the Duryea Carriages. The lines passing through the pivot and across the axle converge at the point of contact of the tire with the ground, thus securing the effect of centre steering.

vantage for this construction, it is claimed that the force of a collision is delivered at or about this line of incidence, rather than on the hub or its axle connection, thus ensuring greater security, and saving the driver a shock. Another device is to incline the pivot axis inward, leaving the axle horizontal, or nearly so, with the result that, as in the previous case, a line drawn through the pivot strikes the ground at the same point with the periphery of the wheel which is itself in a vertical position.

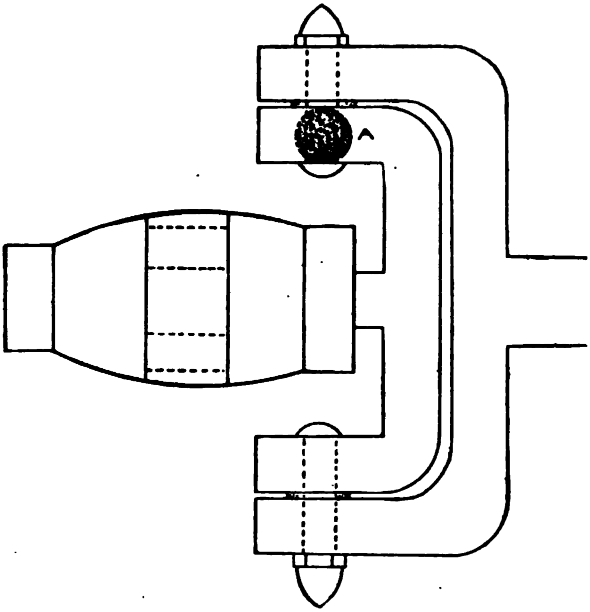


FIG. 36.—The Haynes-Apperson Double Yoke Steering Pivot Axle. The steering arm is attached at A, thus securing the turning effect at approximately the centre of the wheel hub.

Constructional Points on Steering Axles.— It is of prime importance that the construction of the steering knuckles of pivoted axles should be as heavy and durable as the size and weight of the carriage will permit. To neglect this point and attempt a lighter and prettier-looking joint will involve rapid wear and loose bearings to the detriment of good steering qualities. At this point it may be in place to remark that it seems to be a regular superstition with some manufacturers of motor carriages that lightness of construction is the first thing needful in a successful vehicle. For this reason many of them weaken their carriages by using tubular frames with an excessive number of joints, thus making nearly inevitable a rupture somewhere under stress of vibration or constant use on rough roads. One make of American gasoline carriage, which combines a number of exceptionally excellent mechanical conceptions, carries the idea of lightness to such an extreme as to make the various parts far too small to be really serviceable under test conditions. It is probable that the total weight thus saved would not equal one-third of a hundred pounds, a matter of no particular moment, when we consider that, as it is claimed, the motor is of ten horsepower capacity. Contrary to this practice, the worth of a motor carriage, with any type of motor, may be fairly estimated by considering how substantial and durable are the parts exposed to running stress—such are the brake drums, the differential gearing and the steering mechanism—and, whether such parts are of sufficient proportions to admit of easy operation and the resistance of ordinary violence. These qualities are particularly essential in the construction of the pivoted axles, and may be readily recognized in the accompanying figures of typical structures.

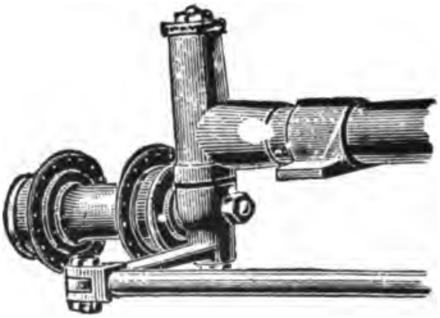


FIG. 37.—Form of Steering Head used on the English Daimler Cars and Others. The steering arm projects from the front of the pivot. Part of the drag link is shown attached.

Other Steering Pivots.—The ends of superior strength and centre-steering are approximated differently by other carriage builders. The Haynes-Apperson Co. uses a double yoke arrangement; one yoke being of a piece with the through axle shaft, the other pivot-bolted at each extremity with the first, and carrying the axle spindle at its centre. The National Automobile and Electric Co. have a vertical bearing at the end of the axle shaft, instead of the usual fork, and within this works a short stud piece carrying the horizontal spindle at the base, the steering arm being bolted at the top. This device seems to be a simplified variation of the one used on the Panhard vehicles, which have a similar upright bearing, or cone pivot, carrying an axle stud and axle in similar fashion, but with the steering gear attached at the base.

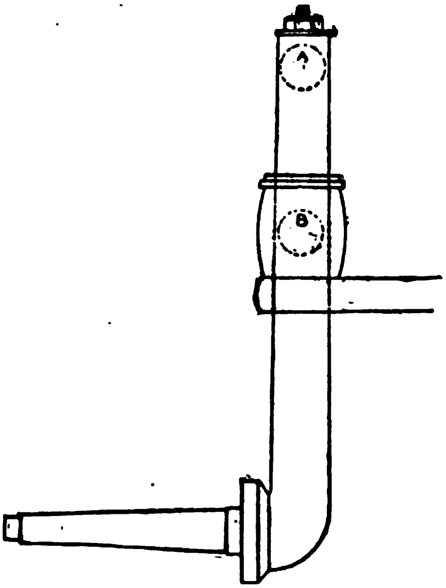


FIG. 38.—Form of Steering Pivot and Axle used by the National Automobile and Electric Co. The steering arm is attached at the point marked A.

Pivoted Wheel Hubs.—Several manufacturers, most notably the Riker Electric Vehicle Co., have attempted to improve the operation of the pivoted steering wheels by enclosing the pivot and lever arm attachments within a hollow hub. The construction includes a hollow cylinder or tube length, which is penetrated by the end of the axle shaft and pivot-bolted to it, so as to turn in either direction under impulse from a steering handle fixed to its inner end and running parallel with the main axle shaft. Around the edges of this pivoted tube run two hard steel cones which engage a train of ball-bearings enclosed in a circular ball-race or retainer fixed on the inside circumference of another and larger tube or box, which forms the hub of the wheel, and runs freely upon the first, the pivoted box, on the train of ball-bearings. This device bringing the pivot exactly at the centre of the wheel is an eminently effective means of accomplishing easy and perfect steering. The construction must, however, be strong and comparatively heavy, so as not to achieve ease of operation by a sacrifice of durability.

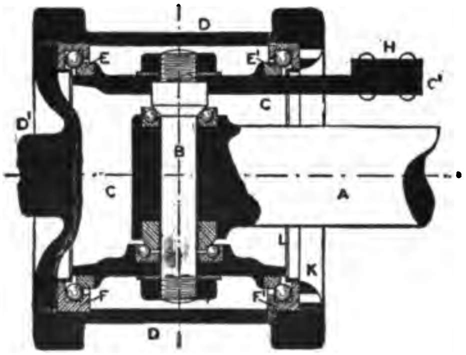


Fig. 39.—Pivoted Steering Hub used on the Riker Carriages. A is the axle shaft; B, the pivot connecting A to the tubular swinging hub, C. E and E' are circular cones which bear on the balls mounted in the ball races, F and F', thus permitting the hub D to rotate independently on the inner tube, C. The steering arm, H, attached to C turns both C and D on the pivot, B.

Numerous inventors have adopted the general idea of placing the pivot within the hub, and effecting the steering by lever and swivel attachments, but the Riker hub is typical of most such devices. The Clubbe and Southey pivoted hub operates on a simpler plan. The fork, or yoke, on the through axle shaft is slightly bent forward at the end, so that a pivot bolt through the eyes pierces a boss attached tangent-wise to a short tubular axle bearing, in which the stud axle, carrying the wheel, revolves freely. The hub is hollow and hemispherical, so as to contain the whole mechanism of the pivot joint, which is slightly forward of the centre, giving a caster action to the wheel in turning. The steering arm is attached to the axle bearing about midway in its length and opposite to the pivot boss.

Requirements in Steering Motor Carriages.—While the novice in mechanics may consider that some of the details and contrivances, thus far described, are quite unnecessary, he will readily recognize their importance when the facts are explained. Thus, when informed that the steering wheels of an automobile must, in turning the vehicle, describe concentric arcs, on radii which differ in length by the distance between the wheels, he will understand that the axle of each must project from the perch at an angle diverse from that made by the other. The arcs thus described must be concentric in order to maintain both wheels in the same direction, without side-slip or resistance; they must be on radii of differing length, because, as is obvious, two parallel wheels, separated by even a minute distance, cannot run in the same tire track. The wheel axles must project from the transverse axle-tree at different angles, because the two wheels, having the same diameter, no matter how their relative speeds may differ, will by any other arrangement fail to run in the same curved direction. This principle is not applied in the steering of horse-drawn carriages for several reasons: (1) The wheels, being carried at either end of a centre-pivoted swinging axle-tree, are always held on the radius of the turning arc. (2) The steel tires

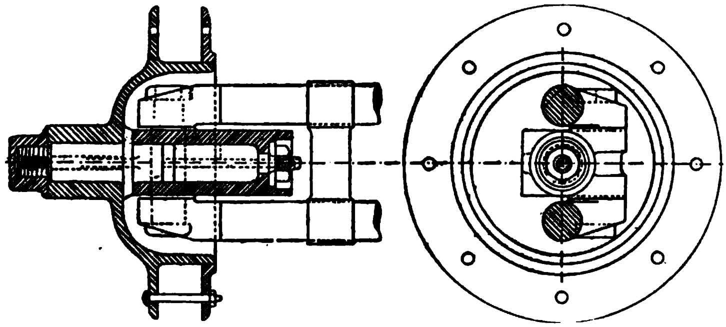


FIG. 40.—The Clubbe and Southey Pivoted Steering Hub used on the Carriages of the Electric Motive Power Co., of England. As may be seen, the pivot is to one side of the axle, thus giving the wheel a true caster movement in turning.

Angles of the Steering Axles.—With an understanding of the positive necessity of providing some means to keep both the steering axles of a motor carriage on radii from a common centre, in order to neutralize the tendency to side slip and skidding, and secure positive control of the vehicle's direction, it is evident that some arrangement must be included for varying the angles of the two from the transverse axle bar. As may be readily understood, when a carriage's travel is changed from the straight-ahead direction to a curve, the steering wheel moving on the in-track, or smaller arc, must assume a greater angle at the axle than the outer wheel, which moves on the larger of the two concentric arcs. It is further evident that such variation of axial angles must be accomplished by some device at the steering arms of the stud axles. If these steering arms be fixed at right angles to the axles, so that the transverse drag-

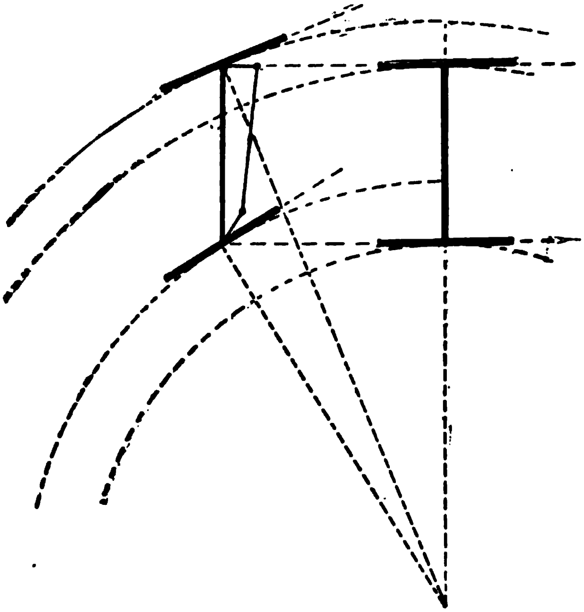


FIG. 44.—Diagram Illustrating the Position of the Steering Wheels in Turning. As will be seen, they both are tangential to arcs described on a common centre, as is necessary in order to describe such concentric arcs and give positive steering, when the motive impulse is from behind.

link is of a length about identical with the distance between the wheel bases, any effort to turn the wheels in steering will shift the angles of both arms with the fixed axle-tree equally, hence, causing the axles to assume positions as radii from different centres. The result will be that the outer wheel will describe an arc tending to cross those described by all the other wheels, and may slide or rub, without revolving, as much as one foot in every six. Such a procedure must, of course, retard the progress of the vehicle very seriously, and, from the uncertainty of steering involved, must be particularly troublesome, even dangerous, on narrow turns. It is evident in this case that the outer wheel axle is at too great an angle, or that the inner is at too small an angle. The simplest method of at once obviating this trouble and also securing the proper angles of the axles is to incline the two steering arms inward from the right angle and make the transverse drag-link shorter than the distance between the axle

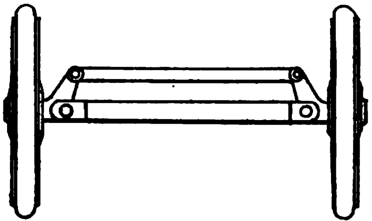


FIG. 45.

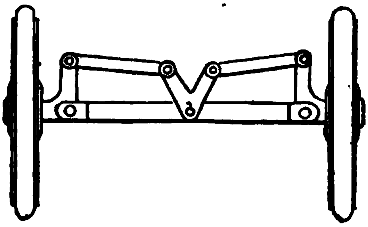


FIG. 46.

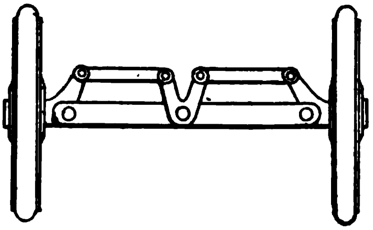


FIG. 47.

FIGS. 45, 46 and 47.—Diagrams of Motor Carriage Forward Axles, showing three arrangements of link bars and steering arms. In the first the steering arms are inclined inward at the required angle and connected across the carriage width by a single link. In the second the steering arms are fixed at right angles to the axle-tree, and the angle of inclination is made at a centre pivoted bell crank. In the third the angle of inclination is divided between the steering arms and the central bell crank. Theoretically, the sum of the angles in the third figure is equal to that in the first, and to the angle of the bell crank in the second.

pivots. If the drag-link be forward the axle-tree, the steering arms are inclined outward.

With this arrangement, as may be readily understood, any effort to change the direction of the travel will cause the arm of the outer wheel to approach the right angle with the transverse through axle bar, and cause the arm of the inner wheel to move proportionately away from the right angle. Moreover, since the end of the transverse drag-link attached to this inner axle-arm must, in the act of thus widening the angle, be approached nearer and nearer to the immovable through axle bar, it must describe an arc, thus passing through a greater number of degrees than will the opposite, or outer, end. Consequently, the object of securing a greater angular inclination for the axle of the inner wheel will be accomplished and the proper difference for all usual conditions between the angles of the two, approximated. That is, although it generally happens that the angular inclination of the steering arms works best on curves of radius midway between the extremely long and extremely short, it has been found that

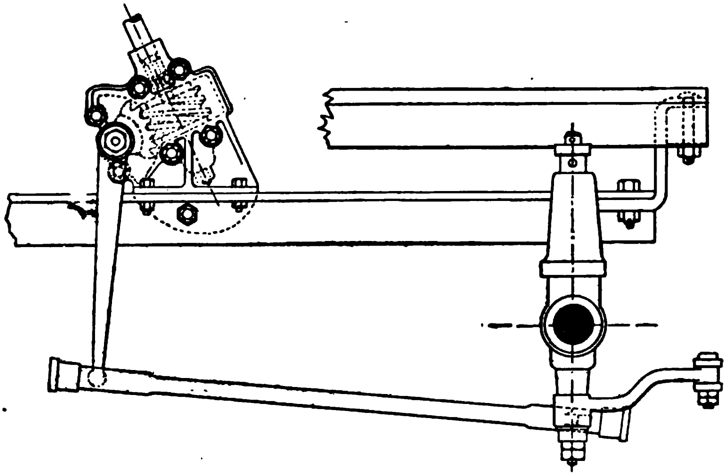


FIG. 48.—Steering Connections of the Panhard Carriages. The spindle of the steering hand wheel carries a worm gear at its base, which actuates a toothed sector, as shown. This swings an arm and moves the drag-link attached to the arm at the base of the steering head. The transverse drag-link connecting the two steering heads is attached to the arm extending from the front of the carriage. The link between the steering head and the sector arm has ball joints and can adjust the distance as the carriage rises and falls on the springs.

the difference is not sufficiently great to disturb the parallelism of the described arcs or cause damaging slips and skidding.

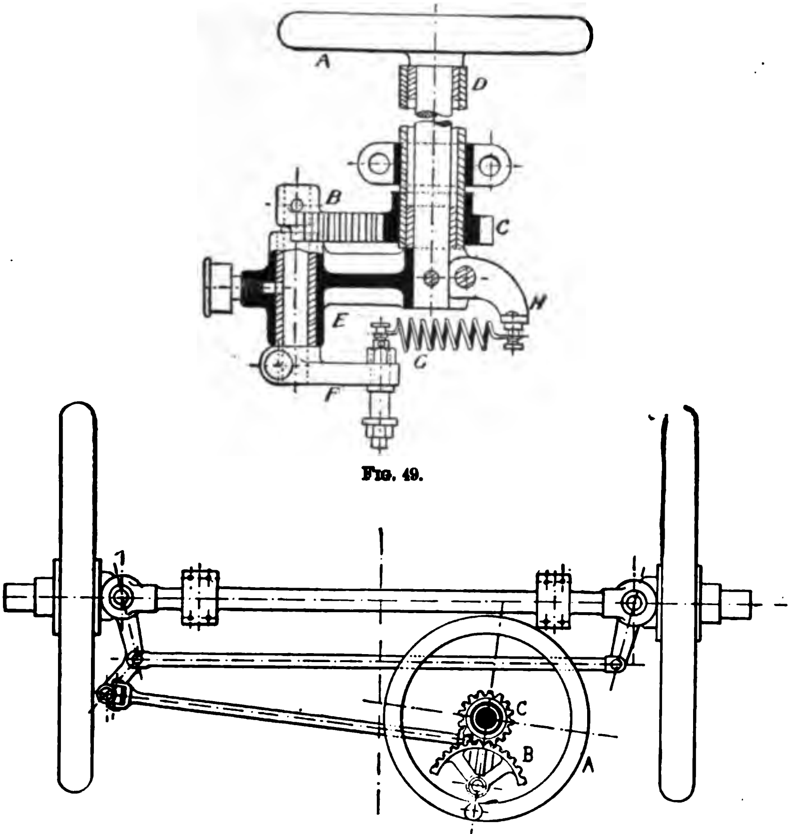


Fig. 49.

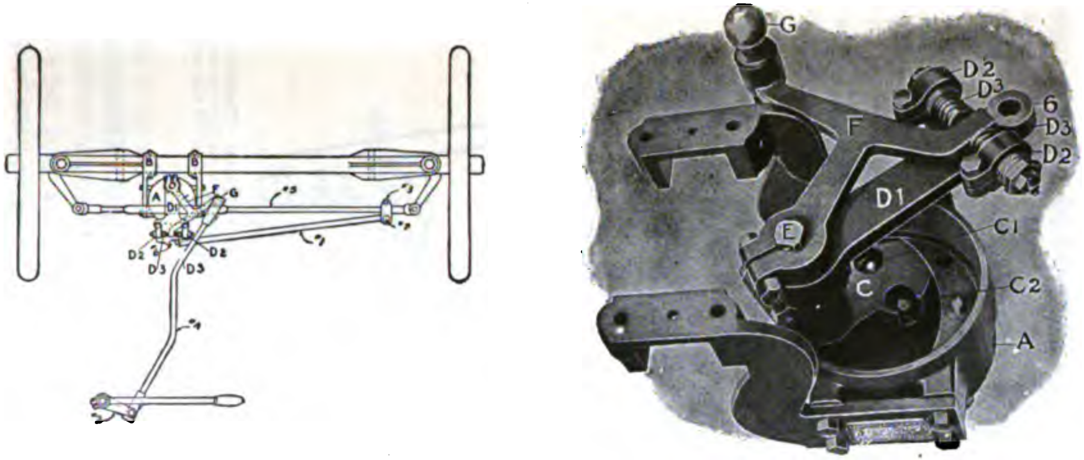
Fig. 50.

Figs. 49 and 50.—The Steering Arrangement of the Gobron-Brillie Carriages. In both figures A is a hand wheel, at the end of whose spindle, D, is an arm, E, to which is pivoted a toothed sector, B. The arm, E, being moved as the wheel, A, is turned, carries around with it the pivot of the sector, B. This sector meshes with the pinion, C, turning loose on the steering pillar, as shown, and is accordingly rotated through an arc. Thus the arm, F, attached to the pivot of B, on E, has a double motion, which involves that the slightest movement of the wheel, A, is unusually effective in actuating the steering arms, through the link attached, as indicated, to the end of F. Also, any stress at the wheels is unable to reverse or disturb the movement thus directed. The spring, G, attached to the arm, H, serves to steady the movement and restore F to normal position when required.

Arrangement of the Steering Handle.—The steering arms on the pivoted axle bosses are connected across the width of the carriage by a drag-link bar, which transmits the impulses given at the wheel or lever by the driver's hand. Most often the attachment is made by a second link bar, attached at one end to one of the steering arms, and, at the other, to the steering wheel or lever, so that this particular arm is dragged or pushed, according to the desired direction in steering. The majority of American motor carriages are equipped with a handle and lever —sometimes in the centre of the vehicle, sometimes at the side— while, in Europe, the hand wheel is the most typical arrangement. The accompanying diagrams show several typical methods of arranging the steering mechanism with reference to the steering link. One of the most common devices is that used in vehicles of the De Dion voiturette type, described as the "ordinary bicycle steering." The handle bar and post may be vertical or inclined, and is connected with the steering device in front by link rods, gears or chains. On some of the Panhard vehicles the link bar actuating the steering arm is jointed to a toothed sector which engages a worm thread on the end of the rearwardly-inclined shaft of the hand wheel before the driver's seat.

As regards lever steering and wheel steering it is mostly a matter of design. The first objection to the lever that occurs to the mind of a novice is that, if attached to a vertical steering head and of sufficient length to be convenient to the driver's hand, a larger arc will be described than is perfectly comfortable.

On this account, however, most lever steerings, operate not directly on the steering head, but through intermediate levers by which the power may be varied to suit the requirements of each turn. Generally speaking, a short steering lever turned at a considerable angle to produce the required deflection of the steering gear is preferable, although, in reality, it becomes a reduced and modified form of steering wheel. By lessening the load on the front of the carriage, by properly inclining the steering heads, and by providing to avoid all lost motion, the steering effort may be so reduced as to make possible the use of a short lever, such as is used on the Duryea and De Dion vehicles, with the accompanying advantages of easy, ready handling and small arcs.



FIGS. 51 and 51A.—The Lemp irreversible steering check and connections, as used on the Knox gasoline and electric vehicle cars. The body, A, has upper and lower chambers divided by a plate. The upper chamber is a reservoir which insures the lower or checking chamber proper being always full of glycerine, which is supplied through a hole in the top cover. The chamber is divided by the radial vane C forged with an upward projecting shank to which arm D 1 is strongly keyed. The bottom of C is recessed to contain a small rocking piece with two fingers, which push upward against the ball checks, C 1 and C 2, to lift one or the other from their seat, by a slight angular movement of the stem E extending down through D. One of the arms of the three-armed lever F is firmly clamped to stem E, which is squared to receive it. The hand-steering lever is connected to the ball G on another arm of lever F. Thus, moving lever F one way lifts C 1; moving it the other way lifts C 2. This allows the glycerine to flow down past the ball lifted through the recess in C and up past the other ball, which lifts itself, to the other side of the chamber, thereby allowing the vane C to move. As it is necessary to lift a ball before D 1 can move, there must be a slight relative motion between lever F and arm D 1 which has connection with the steering knuckles at its outer end, 6. This relative movement is taken up by the spring plungers D 3, which bottom against adjustable stops at the end of their movement, so that after the springs D 3 are compressed sufficiently to open the ball valves, the effort of steering is transmitted through the plunger stops directly to the ears D 2, which are an integral part of arm D 1. These parts are all made very massive to resist the road shocks which are transmitted through the arm D 1 direct to C and then against the glycerine.

Practical Points on Steering Angles.—In general, the steering angle of an automobile carriage, which is to say the sum of the inclinations of the two steering arms from the right angle, is between fifty and sixty degrees, giving an inclination for each arm of between twenty-five and thirty degrees. Some of the best makes of carriage have it at or about twenty-five degrees. As shown in the accompanying diagrams, however, various designers have modified the typical arrangement of inclining the steering arms inward and using a short drag-link to connect them. Some have adopted the device of placing the arms at right angles and using a link in two sections connected to a fork or bell crank having the total required angle, fifty or sixty degrees, and pivoted at the centre of the fixed axle bar. Others have so combined this with the first-named construction as to divide the angle between the centre-pivoted bell crank and the steering arms, making the former, say thirty degrees and the two latter fifteen degrees each. The primary object achieved in either of these devices, as compared with those previously named, is to

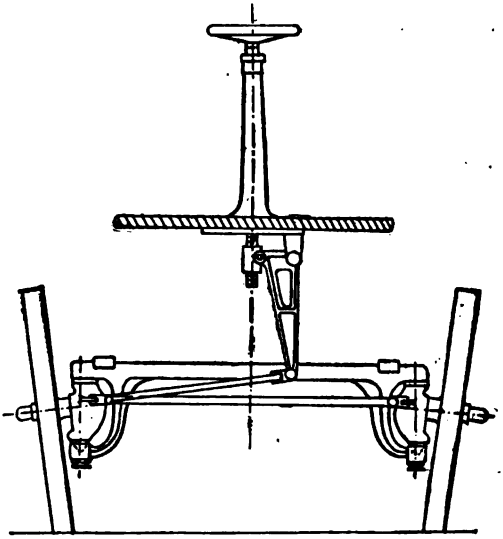


FIG. 52.—Steering Arrangement of the Clarkson-Capel Steam Wagon. The spindle of the steering wheel carries a screw at its end, which works a boss, as the wheel is turned, thus actuating the lever and drag-link attached to the arm of one of the axle pivots.

ensure the end of ready manipulation of the steering lever. The first-named construction is the one best suited to carriages having the steering pivot in the theoretically correct place—within the hub. When for structural reasons the transverse drag-link bar is placed in front of the axle-tree, a position preferred by several manufacturers, the steering arms attached to the bosses of the swinging axles are inclined outward, instead of inward, at the angles found most suitable with reference to the width of the vehicle between the wheel pivots and to the diameter of the wheels. A very useful construction, used on the Duryea carriages and others, is to incline the upper end of the axle boss, or pivot, inward toward the centre of the vehicle, so that a line drawn through the axis touches the ground at the centre of the pneumatic tire. This achieves not only the desirable end of centre-steering, as already mentioned above, but also allows a certain inclination, or rake to the steering wheels, as in a bicycle, when making a turn. The rake is a positive advantage to ready steering qualities, when the inclination of the axle pivot is not at so great an angle as to bring unusual side strain on the wheels. Other things being equally favorable, it is also efficient in reducing the steering effort.

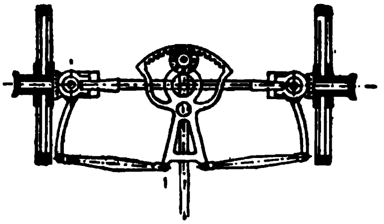


FIG. 53.—Steering Arrangement of the Amadèe Bolee Steam Coach (1881). A hand wheel spindle carries a spur pinion at its base, which working on an internal geared sector, as shown, operates the bell crank, actuating the two transverse drag-links.

CHAPTER FIVE.

VARIOUS DEVICES FOR COMBINING THE STEERING AND DRIVING FUNCTIONS.

Front Driving and Steering.—It will require very little reflection to understand that to drive direct on a pivoted steering wheel must involve a peculiar and carefully adjusted gearing, so that the two functions, driving and steering, may be exercised without interference. Were it possible always to apply the power to the forward wheels it would be advantageous in a number of particulars. Since, however, its accomplishment demands the use of crown or bevel gears, with a consequent strength and weight of construction, it is not perfectly practicable in the lighter patterns of motor carriages. The accompanying figure of a combined driving and steering device, as used in some of the Hurtu electric cabs, shows one arrangement of gearing for accomplishing the result. Here *I* is the armature of the motor, *NN*, the magnets and *B*, a frame supporting the armature spindle which rotates on the axis, *XX*. To this spindle is attached the spur pinion, *P*, which meshes with the pinion, *r*, turning on the axis, *yy*, within the boss of the steering pivot. The spur pinion, *r*, is made in one piece with the bevel pinion, *a*, and this latter engages the toothed bevel ring, *b*, which is clamped to the spokes of the wheel, *RR*. As may be understood, it is possible to swing the wheel, *RR*, on the axis, *yy*, fixed in the yoke, *E*, without interfering with the transmission of driving power from the pinion, *a*, to the bevel ring, *b*, thus permitting the vehicle to be steered and driven on the same wheel.

A more recently patented device of the same description for electric wagons uses a separate axle for each steering driver, on which is mounted a separate motor. The power is transmitted by a spur pinion engaging an internally-geared ring secured to the spokes of the wheel, and the whole device, axle, motor and wheel, being pivoted to the end of a rigid transverse bar, may be turned by the steering gear. The steering pivots are operated by a worm gear at the top of each being engaged by a worm pinion at the extremity of a transverse rotatable bar. In either of these devices the act of steering may be accomplished without moving the motor armature.

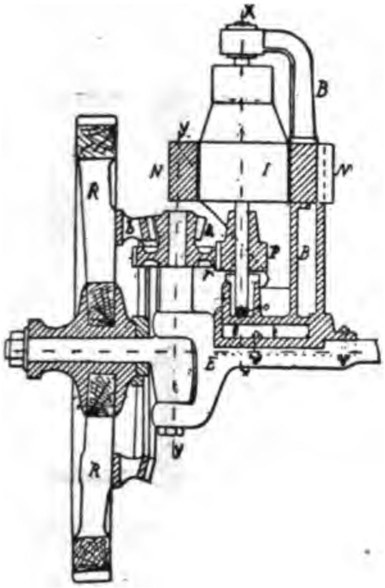


Fig. 54.

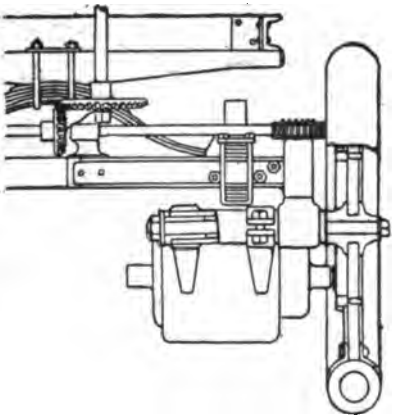


Fig. 55.

Fig. 54.—Motor Steering Wheel of the Hurtu Cabs. A drag-link attached to the arm of the pivots can turn the wheels without disturbing the operation of the motor.
Fig. 55.—Steering Motor Wheel Arrangement, by which a worm gear and pinion device, actuated as shown by bevel gears, turns the stud axle entirely around with the attached motor and gearing, without interrupting a steady drive.

All-Wheel Driving.—Numerous devices have been introduced for the purpose of driving on all four wheels of a motor carriage. Most such are objectionable, however, on the ground of greatly complicating the mechanism and thus proving nearly impracticable for lighter kinds of vehicles. The accompanying figure shows one of the best of these, the subject of a recently granted patent. As may be seen, the driving is by two shafts and two sleeves running in the length of the carriage, and transmitting the rotative movement from two separate trains of bevel gears to the front and rear wheels by sets of universal joints. The front wheels rotate in pivoted bearings, so as to be effectually turned in steering, without interfering with their motion on their own axes, or in any way altering the action of the motor. As may be readily understood, a proper arrangement of bevel gearing at the pinions attached to the rotating shafts and sleeves will give the effect of compensating the speeds of the two rear wheels in turning, according to the principles previously explained.

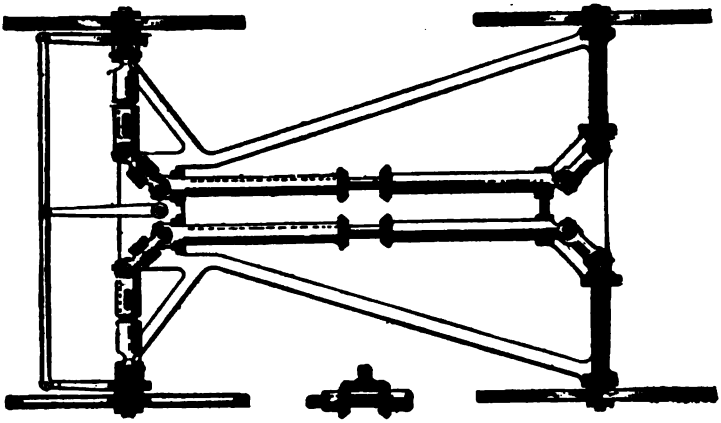


FIG. 56.—Recently Patented Device for Driving on all Four Wheels by a System of Universal Joints. The steering arms are not inclined, since the wheels being driven follow their paths without slipping.

All-Wheel Driving and Steering.—The advantages to be gained in a practical device for applying power to all the wheels are still further enhanced by the additional feature of steering with all four. This is desirable, if we wish such advantages as come by driving on the front wheels and steering with the rear. To steer with the rear wheels only is not always practicable. When the front wheels only are driving it is impossible to propel the carriage up a steep hill, owing to the shifting centre of gravity. With the Cotta steam carriage the power is divided by a quadruple compensating gear into four equal and independent parts, and is then transmitted to each of the four wheels, which are 30 inches diameter with 2½-inch tires. By this arrangement the wheels, each being independent of the others, are allowed freedom in speed in passing over obstructions or unevenness in the roadway without reference to the travel of

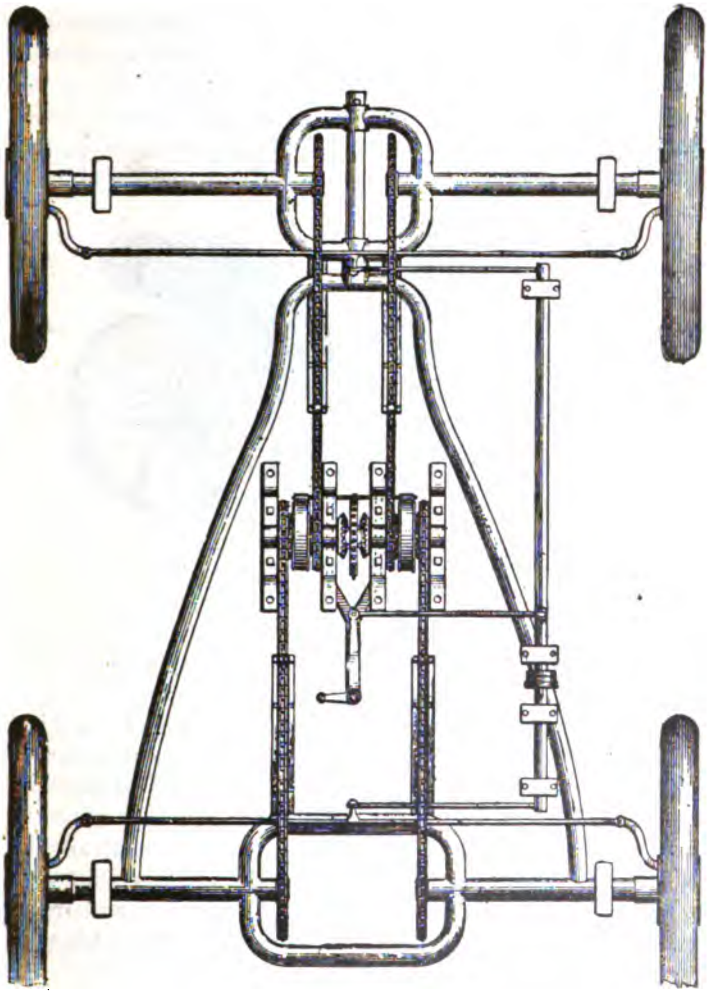


FIG. 57.—Cotta Carriage Frame for Four-wheel Driving and Steering. The motor drives on a balance gear at the centre of the frame, whence motion is transmitted to all wheels by chain and sprocket connections. All four hubs are pivoted for steering, and are connected in pairs across the width of the frame by drag-links. The two links are geared together, as shown, so that the travel of all the wheels may be varied at once by the steering lever.

any of the others, and under all conditions each wheel receives one-fourth of the power, and does its share of the propelling of the vehicle. It is plain to see the necessity of such a compensating device, when we consider that, on a perfectly smooth roadway and traveling straight ahead, each wheel would make a different number of revolutions in a given distance, owing to the fact that it is impossible to have tires inflated exactly alike, and also that some wheels will carry more weight than others, depressing some tires more than others and giving them a diminished radius and less circumference.

FIG. 58.—The Pretot Fore-Carriage shown attached to a Victoria Carriage. The attachment is on a fifth wheel running on roller bearings, and turning by geared connections with the steering hand wheel.

"The Cotta steering pivot is in the direct centre of the wheels, the wheels only oscillating in turning a curve, doing away with all side jar on the steering lever on rough roads, so objectionable in other vehicles. As this vehicle is intended to be a success on bad roads as well as good ones, the makers have arranged to guide all four wheels, bringing the rear wheels around in the same track as the front ones in rounding a curve, and making but two tracks, instead of four, when in the mud, making it as easy to travel on a curve as straight ahead."

As to Rear Steering.— In considering some of the advantages to be derived from front driving arrangements, the idea of steering with the rear wheels only might seem equally advantageous to some minds. But this is impracticable for motor carriages, since its adoption would mean the destruction of good steering qualities. The situation is well expressed in the "Horseless Age": "The objections to rear steering are that, when a carriage is standing near a curb, it is impossible to turn off sharply, as the steering wheel (rear) would run into the curb; and that, when near a ditch or impassable section of the road, in order to turn away from these, the steering wheels (rear) must first run toward them, which may lead to difficulties."

Automobile Fore-Carriages and Motor Wheels.— Among other solutions of the important problem, as some consider it, of combined driving and steering on the front wheels, may be mentioned such devices as the Pretot fore-carriage, manufactured in France and England, and also introduced in the United States. As shown by the accompanying figure, this device is a two-wheeled truck, which may be attached to almost any vehicle by slight alteration, and capable of being turned for steering on a kind of fifth wheel arrangement running on rollers. The fore-carriage itself contains a gasoline motor of between five and ten horse-power, with suitable transmission gear, permitting three speeds forward and a reverse, and is controlled by the single lever to the rear of the steering wheel. Fuel for the motor is carried in the receptacle in front of the dash-board. It is claimed that this device permits easy motion of the vehicle and absolute control, together with ready steering qualities. An American invention of somewhat similar description is the International Motor Wheel, which is, briefly, a single forward drive wheel, carrying on its frame a double cylinder gasoline motor and its fly-wheel. The frame may be clamped to the front of any vehicle, which may be steered by a brake-wheel working on a spur gear. One advantage of the device is that no reverse contrivance is necessary; the wheel needing only to be turned completely around in order to back the carriage when the motor is started.

The American Bicycle Co. recently put on the market a three-wheeled carriage—the "Trimoto"—capable of seating two persons and giving a speed of twelve miles per hour. As in the last-named contrivance, the motor, as well as the gasoline receptacle, are slung on the frame of the forward single wheel. Steering and motor control are both achieved by a single lever coming to the driver's hand over the dashboard.

The Conditions for Good Traction and Steering.—Such machines as above described work very well on good and level roads, but, as a general principle, hanging the motor in front involves insufficient traction and causes the forward wheel to skid even on slight hills, when the weight is mostly over the rear axle. In the early days of motor carriage construction it was commonly believed that overloading the rear, or drive-wheels, involves skidding, whereas the reverse is true, and at the present time the rule is to make them carry the greater part of the load, in order to promote traction. It is obvious, then, that the rear axle is most logically the drive axle, since, when ascending hills the bulk of the weight must come upon it on any theory of construction. Moreover, it must also properly be the load-carrier, since, as has been frequently demonstrated, any attempt to place the greater weight in front only complicates difficulties. Carriages constructed to carry the load on the front axle have frequently exhibited the tendency to slip sideways, particularly when the brake has been suddenly applied. It has not been an

FIG. 59.—Front-Driving Brougham of the Electric Vehicle Co., used in New York City. This model, which is no longer manufactured, represents a construction very suitable for city service, but quite inappropriate for country and general use.

uncommon thing that such carriages would turn completely around on a greasy street, when propelled by sufficient power to cause the wheels to slide. It has also been found that any arrangement that will prevent slipping forward will also do away with the danger of slipping sideways. Hence, a well-loaded rear driving axle may be considered a permanence, not to say a practical necessity in motor carriage construction.

AUTOMOBILE TOPICS.

FIG. 60.—Anti-skidding device on the rear wheel of a Mercedes limousine. A network of braided rope offers sufficient resistance to prevent side-step and skidding on a greasy street.

CHAPTER SIX.

THE UNDERFRAMES OF MOTOR CARRIAGES.

Frames for Motor Carriages.—In general, it may be said, the problems involved in the construction of motor carriage underframes are comparatively simple. They must embody lightness and strength, firmness and some flexibility, and sufficient solidity to resist the destructive effects of motor vibration. The last-named consideration is of particular importance in the construction of gasoline carriages, but is to a certain extent true also of steam carriages, since even with the best-constructed engine of the latter variety, the long-continued stress of vibration is liable to produce strain and breakage, if not properly calculated. In other particulars the frame of a horse-drawn vehicle is fairly typical, except in so far as the conditions involved in mounting a motor necessitate consideration of new centres of resistance to strain.

Horse Carriages and Motor Carriages.—The general situation as regards the constructional relations of the underframes for horse carriages and motor carriages has been summed by Mr. Woods, as follows: "The trouble has usually been that engineers, electricians and mechanicians have been the original authors of the automobile, and their minds have been so concentrated upon the development and perfection of the mechanical and electrical parts that they have entirely ignored the artistic side of it. This was undoubtedly brought about by the indifference and skepticism, as well as opposition, offered the advancement of the motor vehicle from legitimate carriage manufacturers, to whom such men refrained from going for advice. There is no question but that this problem belonged to the carriage manufacturers, and, had they taken hold of it in time, they would have preserved to themselves an industry which they rightly had earned by prior experience and conceptions as carriage producers. * * * * Another point of construction is bicycle tubing, or tubing of that nature, for frame work or running gears—in other words, bicycle construction for supporting the carriage and its weight, as compared with regular and well-known carriage methods of construction. Tubing can, without doubt, be made strong enough, but that is not the question altogether. We must have the entire carriage construction in such shape that it can be repaired by the same class of artisans, blacksmiths, etc., that is now employed by the carriage-makers throughout the country. * * * * * A motor vehicle should be constructed in all of its iron work, its running gear and axles, the method of putting on its springs, etc., as nearly as possible after the methods now in existence in the carriage world, using, as far as practicable throughout the vehicle, standard carriage hardware. In this way the purchaser of an automobile has a resource at his own door for such repairs as he may need from year to year in addition to his regular painting, varnishing and trimming repairs."

Steel Tubing Framework.—There are two principal objects sought in the use of tubular framework for motor carriages—strength and lightness. These desiderata, which are possible in cycles only with this style of construction, are less prominent in automobiles. Thus it is that, while the majority of European machines still adhere to its use, there is a strongly-marked tendency in America toward angle iron frames, and even more familiar combinations. By the use of brazed joints tubular framework is rendered immensely strong; for, as is asserted by numerous bicycle authorities, breakage practically never occurs at the joints. But to properly repair damage requires the insertion and brazing of fresh tube lengths, which, itself, involves special facilities. Another objection, obviously to be derived from existing tubular structures, is that the advantages gained, in point of combined strength and lightness, are very largely neutralized by the necessity of extra bracing and greater complexity, quite readily escaped with the use of angle-iron framework. Thus it is that Mr. Woods, as above quoted, can assert that tubular framework in a 4,900 pound electric cab saves only about 200 pounds weight, while, as we may readily discover, the desirable end of simple structure is not particularly advanced. Furthermore, the æsthetic considerations of the situation are rather against a practice necessitating the use of clumsy-looking pipes, when lighter structures can quite as readily subserve the same ends.

The Stanley Tubing Underframe.— The Stanley underframe, used in the "Locomobile" and several other steam carriages is one of the most representative constructions of its class. As shown in the accompanying figure, the front and rear axle shafts are inserted into straight cross tubes, which are brazed to arched cross tubes, intended to lend additional strength and serve as supports for the longitudinal reach tubes. These reach tubes, two in number, are swivel-jointed to the arched cross tubes, as shown, and further secured in place by stay pieces swiveled at the four corners of the frame and ring—jointed loosely on the reach tubes. This construction permits some flexibility on rough roads. The rear cross tube is divided at the centre to admit the sprocket and brake drum, with the contained differential gear. As additional security the two ends are rigidly joined to the arched tube by perpendicular stay rods, and connected together by a nearly circular guard plate surrounding the sprocket and brake drum. The forward arched cross tube supports the forward spring, which is fixed transversely under the body of the carriage, and in front of the vertical axis post of the steering lever. The rear springs are arranged longitudinally on either side of the carriage, being bolted to the seats shown half way on the curve

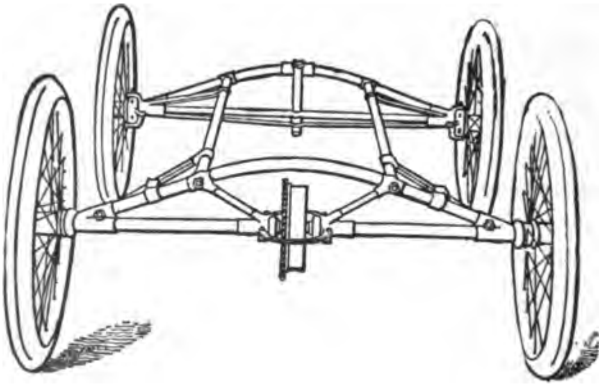


FIG. 61.—The Stanley Type of Underframe used on the "Locomobile" and several other Carriages.

of the rear-arched cross tube. The boiler and engine, as may be seen in a later figure of the "Locomobile" carriage—and this is the most approved arrangement for motors of every variety—are disposed within the body, beneath and to the rear of the seat, forward of the rear axle. This arrangement overcomes many difficulties involved in attaching them direct to the underframe, and is perfectly practicable; since the springs, in compression, move in a line tangential to the circumference of the sprocket wheel, thus merely shifting the radial line between the sprocket wheel and pinion, and enabling the chain to transmit the power without interruption. This could not be the case were the motor suspended immediately above the sprocket, nor would the effect of steady driving be any better achieved by suspending it on the underframe below the springs, as is still done by some manufacturers.

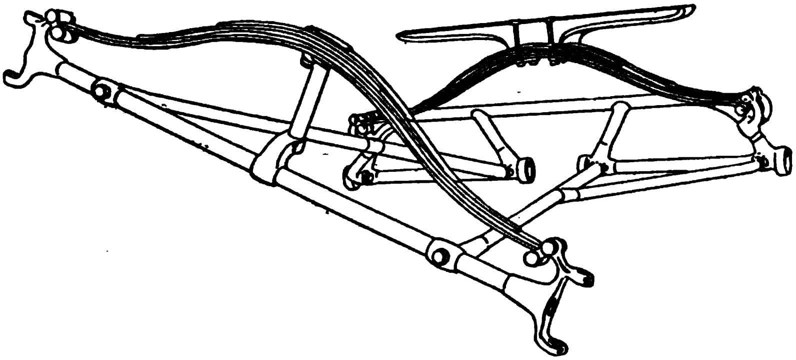


FIG. 62.—The Flexible Underframe of the Reading Steam Carriage.

The Reading Tubular Frame.—Another tubular frame, also intended for steam carriage use, is shown in the accompanying figure. In it, as in the Stanley frame, there are transverse axle tubes at front and rear, the latter being similarly divided at the centre for the sprocket and brake drum. The longitudinal reach rods, however, instead of running parallel and at right angles to the axles, are disposed so as to form a nearly complete triangle, with the forward axle tube as the base and the sprocket near the apex. The joints on the forward axle are swiveled, and on the rear axle are ring pivots, so as to permit the distortion shown in the figure on rough or uneven roads. The stay rods at either side of the reach tubes, joining them to the rear axle tube, are also pivoted, as shown, thus assisting the flexibility, while increasing the strength. The forward arched cross tube of the Stanley frame is replaced here by a semi-elliptical spring, while the same feature on the rear axle is here made continuous with the axle bearings, to which are brazed the centre-divided axle tubes, the three being connected and brazed to stay rods. The rear spring, also semi-elliptical, is jointed to the arched cross tube near the rear axle bearings. The rear axle shaft, however, is rigid with the carriage body containing the motor, so that no distortion of the kind pictured can interfere with the steady drive.

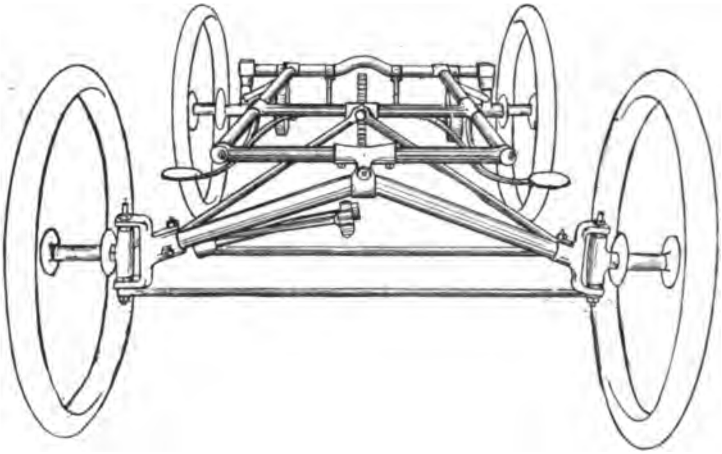


FIG. 63.—The Tubular Flexible Underframe of the McKay Carriage, showing the double swivel jointed front axle.

Other Flexibility Devices.—Several other carriages attain the end of a flexible and distortible underframe by a three-point support and a swivel joint at the centre of the forward axle shaft. This gives the same general effect on uneven roadways, as is shown in the figure of the Reading carriage, allowing the four wheels to run on different planes, but, as is held by some authorities, it is not as efficient in absorbing undue vibration, as some system of jointure involving a four-point support. It has, how-

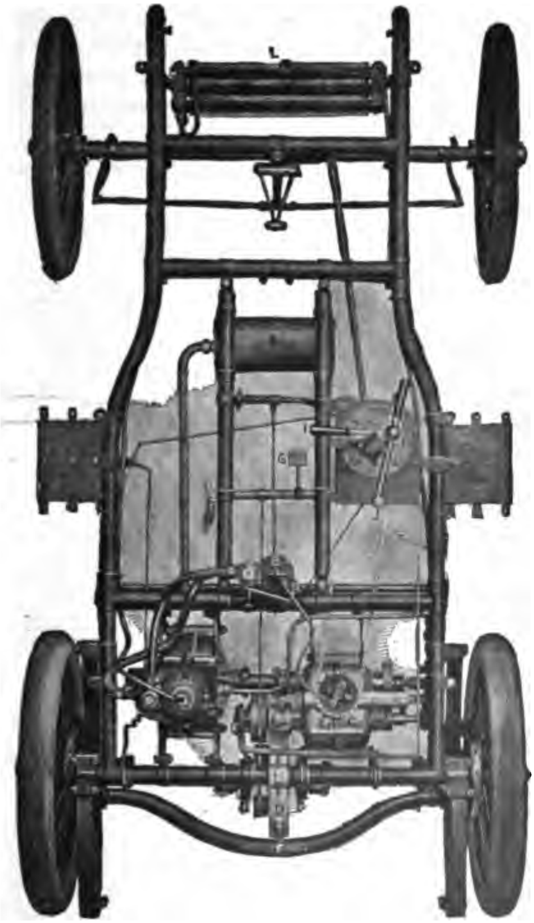


FIG. 64.—Plan of the De Dion & Bouton Underframe and Running Gear, showing the motor and mechanism in position. A, Motor; B, Vaporizer; C, Change of Speed; D, Differential; F, Curved Axle; G, Auxiliary Brake; I, Variable Speed Controller and Brake; J, Steering Handle; K, Muffler; L, Radiator.

ever, been adopted with apparently good results in carriages of all descriptions. The "Steamobile" steam carriage has the reach rods coming together in an angle to the front of the frame, and swiveled at the centre of the forward axle shaft in a yoke, which carries the axle and allows it even greater play in passing over obstructions than is possible even with other methods of swiveling. In this carriage the forward spring is of the usual elliptical construction, placed transversely, or parallel, to the axle shaft,

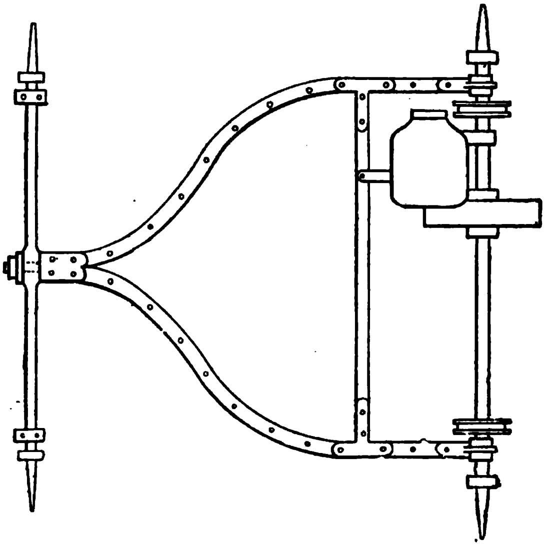


FIG. 65.—Angle Iron Underframe with swivel joint at centre of front axle.

and attached at the top of the swivel yoke. This arrangement is fairly typical of the usual three-point support construction, and has been frequently criticised, because one spring must absorb all the jar incident to the raising or lowering of the wheels. One make of electric carriage, manufactured in Buffalo, N. Y., uses the centre-swiveled forward axle shaft, to which are attached elliptical springs at either side, running with the length of the frame. The result is that, by the use of extra flexible springs, vibration is so reduced as to permit the use of very small rubber tires, while in no way diminishing the effect of a flexible frame.

The Riker Underframe.—One of the best known devices for securing a flexible underframe is embodied in the Riker electric carriages. The construction is of seamless steel tubing throughout, and includes two axle shafts and a cross bar, all parallel in the width of the frame, and two longitudinal reach tubes, each bent inward and carried forward toward the front of the carriage, thus forming a rectangle of diminished width at the front end. Both the reach tubes are ring-jointed over the forward axle tube; one being securely brazed in place, the other, with its attached stay tube being free to turn, so as to admit of raising or lowering the axle shaft, without straining the frame. Both the reach tubes have their rear ends inserted in bosses below, and cast in one piece, with the bearings for the rotating rear axles being held in place by collars in front and screw nuts at the rear. These bosses are thus true bearings, permitting a certain rotary movement of the reach tubes in the effort to accommodate the axles to any unevenness in the roadbed. The contour of the frame is maintained by binding collars at the jointure of the movable reach tube on the forward axle, and by the transverse cross tube at-

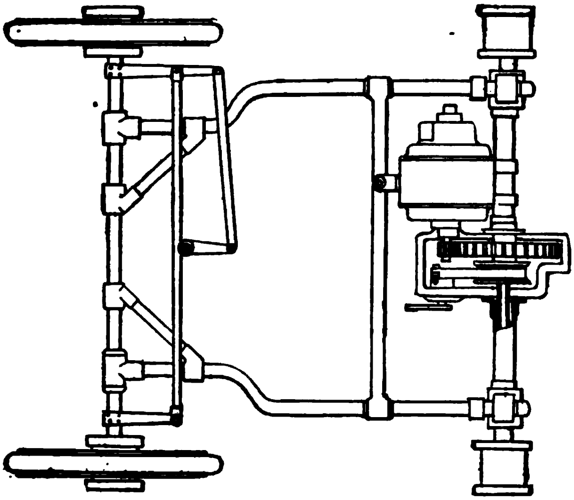


FIG. 68.—The Riker Underframe, showing the swivel connections at front and rear to permit distortion on uneven roads.

tached midway in the length of both. As shown in the diagram of this underframe, the motor is suspended between the rear axle tube, which forms a sleeve over the rotating centre-divided axle, and the midway cross tube, already mentioned as forward of the axle shaft The effect of a steady drive is obtained by attaching the motor and gearing at the same side of the frame with the rigidly attached and braze-jointed reach tube, so that the flexibility which permits a certain degree of distortion in passing over uneven roadbeds, through the loose attachments of the opposite reach, in no way interferes with the interaction of the driving gears. Herein, we see a fundamental constructional principle for a flexible motor carriage frame; that the flexible and distortable portion should involve only that the forward and rear axle shafts may be so twisted as to move on different planes, thus insuring the stability of the carriage body, while, at the same time, maintaining the motor and drive axle in a fixed and invariable relation.

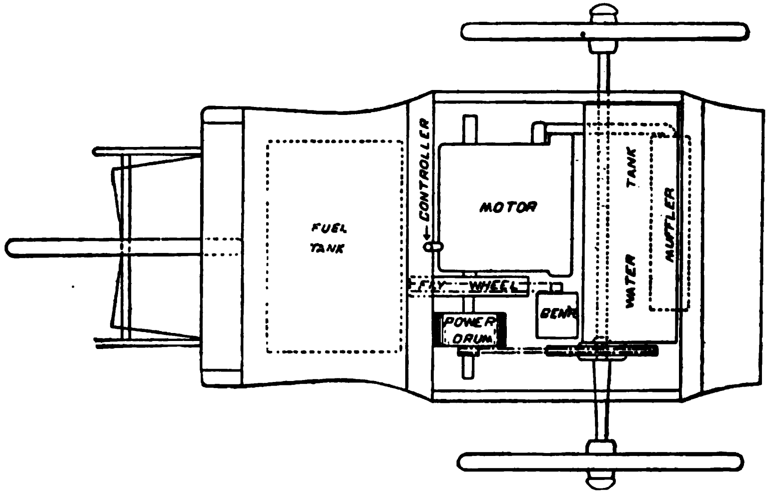


FIG. 67.—Plan of the Duryea Three-wheeled Phaeton, showing the body frame used as attachment for all working parts, dispensing with the underframe entirely.

Dispensing with the Underframe.—The tradition has become so fixed among builders and users that an elaborate and strongly-constructed underframe is indispensable to an efficient and easy-running automobile carriage that any proposition to dispense with it altogether will likely be scouted as impracticable. As a matter of fact, however, one of the most efficient makes of American gasoline carriage—the Duryea Power Co.'s phaeton—avoids the added weight and strength of the frame by the simple device of hanging the axles directly on the springs supporting the body, which is unusually strongly and heavily built. This practice, following closely on the general plan of light horse phaetons, enables the use of a heavier motor and body, with all the involved advantages, while at the same time allowing the full use for driving of much of the power ordinarily absorbed in propelling a heavily-built running gear. The needed effect of flexibility is secured by extra long and resilient springs, a semi-elliptical pair running longitudinally over the rear axle shaft, and a semi-elliptical single spring running transversely over the forward

Fig. 68.—Duryea Four-wheeled Trap. This carriage, like all others made by the Duryeas, has no underframe; the strongly built body serving as a frame to which the axles and springs are hung.

shaft. The accompanying diagram plan of the Duryea three-wheeled carriage and the view of a four-wheeler display the constructional points to advantage. As we shall see later these are the same in both, excepting on the forward wheels.

Three-Wheeled Carriages.—While most of the best known makes of motor carriage run on four wheels, like ordinary horse-drawn vehicles, there are several arguments in favor of using three-wheelers. One of the most prominent constructional considerations is that the principle of "three-point support" largely, if not altogether, does away with the necessity of a flexible underframe to adjust the wheel levels on uneven roads, with the result that, as is claimed by one manufacturer, there can be no "unequal strains in the frame, tending to break or twist it, or disalign the machinery." All the advantages of a rigid frame, which, as we have already seen, must be in some way combined with a flexible frame, in order to obtain an invariable relation between the motor and the drive axle, are thus possible without sacrifice of other qualities equally essential. It is claimed, however, that three-wheelers are more liable

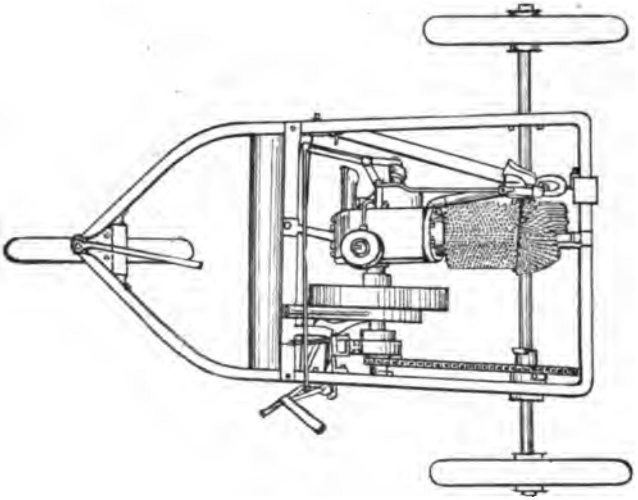


FIG. 69.—Angle Iron Underframe of the Knox Three-wheeled Gasoline Phaeton, showing motor and gearing in position, also steering connections.

to upset than are carriages with four wheels, which would very likely be the case were an attempt made to elevate one rear wheel at too great an angle. But, as may be readily understood, a four-wheeler would be no more stable under such unusual conditions, which would tend either to upset the carriage or twist the underframe entirely out of shape. There is some show of reason, then, in the assertion that a three-wheeler will travel on any road passable to a four-wheeled carriage. For, provided the carriage be properly designed, and the proportions of breadth, length and height, the weight of the machinery and body, and the distribution of the load be accurately calculated, the danger of an upset in passing over any inequality that a sensible driver is capable of attempting would be exceedingly remote.

FIG. 70.—The Knox Three-wheeled Gasoline Phaeton, showing angle iron underframe, three-point support and steering connections.

Advantages of Three-Wheelers.—In a letter to the "Horseless Age," Mr. Charles E. Duryea, of the Duryea Power Co., says: "The writer is free to predict that the future popular two-passenger carriage will be a three-wheeler, because of the many advantages which only need to be known to be appreciated. We are running three and four-wheelers of the same design, side by side over all kinds of roads in this locality, and know by actual comparison that the three-wheeler is preferable in most cases. We submit that actual tests are stronger proofs than theories." In the same letter he says further: "The three-wheeled carriage, if properly designed, rides as easy as a four-wheeler, or so nearly so that the difference cannot be told by a blindfolded observer riding in the two alternately; while the three-wheeler steers more easily, requires less power to propel, starts and stops more quickly, is simpler, lighter, very much better in mud and appreciably better everywhere else." In another letter on the same subject he says:

FIG. 71.—Duryea Three-wheeled Delivery Wagon. This wagon is built on the plan shown in Fig. 67.

"While we supply four-wheelers to those buyers who do not wish the three-wheeler, we are confident that the three-wheeler is the best machine of the two, and have demonstrated the same many times by actual comparison. There is one less tire to watch, fewer parts to look after, less weight to carry, one less track, and consequently less road friction, which means less fuel, less heat, less noise." It has also been claimed that three-wheeled carriages have the additional advantage of vibrating less on rough roads, some claiming a decrease in this respect on a ratio of 3 to 4. But this is not so certain, according to other findings. The manufacturers of the Knox gasoline three-wheeler, which is enjoying an increasing popularity in some quarters, evidently consider their own machine, at least, highly efficient in this respect. They say: "We use the principle of *three-point support* * * * wherever possible, the frame being supported on three wheels, the engine being attached to the frame at three points, and the body being mounted on the frame by three springs. Rough or uneven roads have little power to harm such construction."

Steering Gear of the Knox Carriage.—With the use of four wheels, as we have already seen, ready and positive steering may be attained by observing a few simple and obvious constructional principles, prominent among which is the requirement of keeping the balance of leverage as near the axis of the wheel as possible. This end is made even more practicable with a three-wheeled vehicle by hanging the forward single wheel on a fork, after the manner of an ordinary foot-propelled bicycle. Such a course is actually followed in the Knox carriage, for which the manufacturers claim "easy and reliable steering" with the following advantages: "The steering action is the same as in a bicycle that can be ridden 'hands off'; closest possible connection from hand of operator to steering wheel; entire absence of levers and connections to cause lost motion or trouble to operator; the vehicle will turn in a nine-foot circle under its own power; very short turns may be made at high speed without danger of capsizing." Even with all the excellent features above enumerated, it is doubtful if the method of controlling the steering wheel by a lever attached direct to the pivot of a swinging wheel is altogether the best construction for a motor vehicle. For, as is evident on reflection, a hand lever of sufficient length to give the steerer a positive turn, without using too much strength, will describe an arc of such dimensions as to annoy the riders and often necessitate long reaches. It is possible that some form of worm gear and pinion device would achieve all the excellent results claimed without the difficulties involved in a long lever.

Duryea's Steering Head—The steering wheel of the Duryea three-wheeler is not hung in a fork, but turns on an axle shaft attached to the two curled bars extending to the front of the carriage body. In all respects, therefore, the three-wheeler of the Duryea Co. differs from the four-wheeler only in the fact that a single wheel is thus attached, instead of the semi-elliptical spring, carrying a through axle for two knuckle-jointed wheels. The steering head is an ingenious and highly efficient device.

which has been in use on these carriages for nearly four years. As shown in the diagram, the forward wheel has twelve spokes mounted on mortises on a malleable ring, in which are screwed hardened steel ball cones, provided with a locking device for fastening after adjustment. This malleable ring when mounted revolves on a ball race, containing thirty three-eighth-inch balls, which is screwed to the cylindrical steering head. At the top and bottom of the steering head are mounted hardened cups for the steering pivot cones, the one fixed permanently, the other adjustably in the cross bar or support, which carries the front end of the vehicle. As shown in the diagram, the upper cone may be screwed in or out to adjust the bearing at this point. It is held in place by a clamp, while the lower cone generally turns on balls, as shown. By this arrangement the steering pivot is brought directly into the plane of the wheel, as in a cycle, so that there is no jar on the steering lever, or need of unusual effort on the part of the driver. Moreover the arrangement is highly efficient in ensuring a constant direction, particularly when traveling on level roads, a point highly desirable in a pleasure carriage.

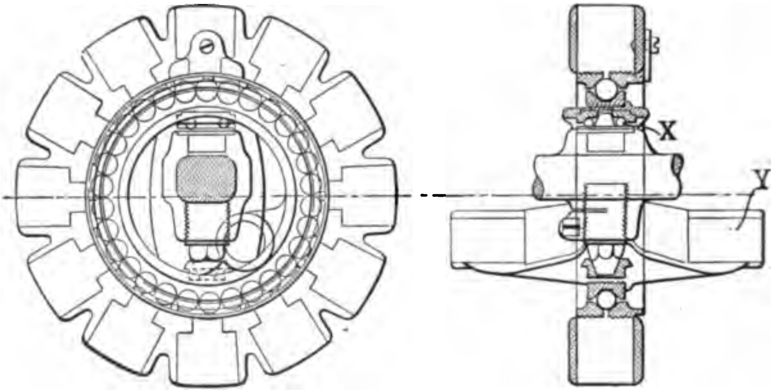


Fig. 72.—Steering Head of the Duryea Three-wheeled Carriages. X is the support of the wheel which turns on the ball race shown. Y is the attachment of the steering links.

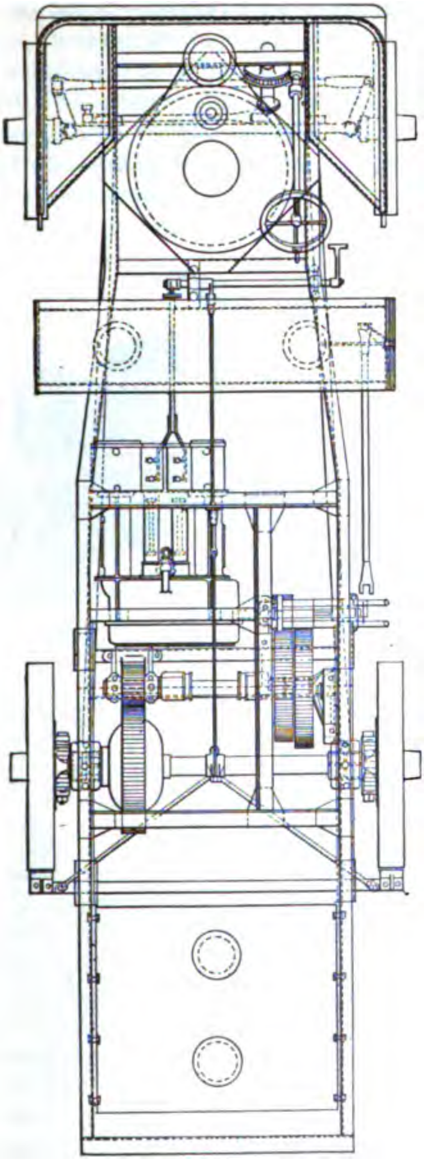


FIG. 78.—Plan of Body and Underframe of Thornycroft Long Frame Lorry. The dotted lines between the axles indicate the reaches which constitute the underframe.

The Present Situation on Frames.—Some of the foremost manufacturers of motor carriages at the present time hold to the conviction that an elaborate underframe is rather a useless complication than an advantage in any sense. This means that, as is being increasingly understood, the same framework may serve for the body, the motor and the running gear, giving a combination that is lighter and stronger than where two or three separate frames are used, besides saving space, material, labor, care and repairing, and increasing the neatness, while descreasing the weight and the cost. The body must be mounted on springs, and it is the best construction, particularly where high speeds are contemplated, to mount the motor in the body. In his statement that the experience of carriage builders is preferable in the matter of underframes, to that of bicycle builders—for it was entirely from bicycle precedents that tubular framework was ever adopted—Mr. Woods seems to be in accord with several other authorities. Even with the most carefully planned tubular frame the stiffness

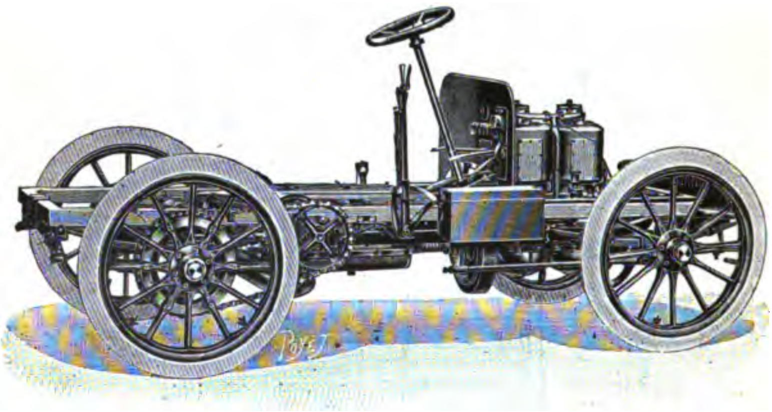


FIG. 74.—Running Gear of the Charron carriage; one of the newer makes of French automobiles, constructed on the general models of the Panhard-Levassor. In this carriage the running gear consists of a heavy, trussed, wooden body frame to which the wheels are hung by the springs, placing the machinery entirely above the axles. The same general plan is followed in the majority of heavy touring cars, although some manufacturers use channel steel frame work. Very few large cars at the present time use any variety of tubular underframe.

of the construction is poorly compensated even with the use of swivel joints, and some of the best known makes of motor carriage with tubular frames are constantly giving trouble from this cause, involving constant damage and consequent repairs. On the other hand, it must not be forgotten that, unlike both carriage and cycle, the automobile is a locomotive, and that, as such, its peculiar conditions demand constructions to which no former experience is precisely analogous. In no matter more than underframes is it so essential to bear this distinction in mind, and in no point is it so apparent that the ultimate or permanent type of motor carriage will depart quite entirely from the precedents of horse-drawn vehicles. In a letter to the author, Mr. C. E. Duryea says: "The use of steel wheels and tubular construction is an outgrowth of cycle experience, but engineers make a mistake who attempt to apply their experience indiscriminately to carriages, for the carriage problem is not a single-plane problem. Both the cycle and its wheels receive strains, and in a single plane, while cycle riders save themselves and the machine by standing on the pedals on rough spots. The automobile rider never does this, while the constant torsions and wrenchings of a four-cornered frame are simply indescribable. On this account a three-wheeled construction is much longer lived and will undoubtedly prevail in the end."

Fig. 74a.—An American Gasoline Vehicle, equipped with side spring frame, after the fashion of several models of horse carriage. This style of underframe is very suitable for light motor carriages, overcoming many of the disadvantages of the usual spring constructions.

CHAPTER SEVEN.

SPRINGS AND COMPENSATING DEVICES; RADIUS RODS AND JOINTED SHAFTS.

Springs for Motor Carriages.—Like all varieties of vehicle at the present day, automobiles have the body suspended from the axles or underframe on suitable springs. With them, also, the usual function is subserved, absorbing and counteracting jars and cumulated vibrations incident on roughness in the roadway or a high degree of speed. In the present state of the motor carriage industry, there are few data regarding the proportions and construction of springs, best suited for different purposes; the matter being largely one of empirical considerations and practical experiment. We may readily understand, however, that motor carriages, being intended primarily for high degrees of speed, involve conditions and considerations found in neither horse-drawn vehicles nor railroad cars. The latter, although traveling at speeds often 100 per cent. greater than the average automobile, run upon an even and comparatively unresistant roadway—the track of steel rails—while the former, although built for the ordinary highways, as are automobiles, are seldom calculated for any but very moderate rates of speed. Railroad cars must, thus, provide against a maximal speed, with a minimal road roughness and resistance; horse carriages, on the other hand, must provide against a maximal roughness and resistance with a minimal speed; motor carriages must be able to attain high speeds and, at the same time, resist the annoying and destructive effects of roadways, inevitably irregular as to resistance and other conditions of surface. As a general proposition, therefore, we may assert that such springs as will promote comfort will prevent undue wear and tear on the motor and parts, which, in fact, makes the end of easy riding for the passengers the prime consideration.

The Theoretical Working Unity.—In no part of construction is it more essential to consider the road and the vehicle as a working unit than in the matter of calculating for springs, and in no point is there a greater element of uncertainty and a greater variableness in running conditions to render all calculations unreliable and inexact. The general situation is well expressed in a recent article on motor vans in the *London Engineer*, which speaks as follows:

"The prime fact with which engineers have to deal is that the success or failure of any design mainly depends on the nature of the road on which the van is to be worked. The V-slides of a planing machine are integral parts of the whole. The permanent way of a railroad and the rolling stock constitute together one complete machine. In just the same way the King's highway must be regarded as an integral part of all and every combination of mechanical appliances by which transport is effected on the road. In one word, if we attempt to dissever the road from the van, we shall fail to accomplish anything. Two or three years ago, the maker of a steam van told us that he was surprised to find how little power was required to work his van. He had been running it on wood-paved streets. A week or two later on he was very much more surprised to find that on fairly good macadam after rain he could do next to nothing with the same van. In preparing the designs for any van, the quality of the roads must not for a moment be forgotten; and it will not do to estimate the character of the road by anything but its worst bits. A length of a few yards of soft, sandy bottom on an otherwise good road will certainly bring a van which may have been doing well to grief. Curiously enough we have found this apparently obvious circumstance constantly overlooked. This is not all, however. A road may be level, hard, and of little resistance to traction, and yet be very destructive to mechanism. This type of road is rough and "knobby"; it will shake a vehicle to pieces, and the mischief done by such roads augments in a most painfully rapid ratio with the pace of the vehicle. Jarring and tremor are as effectual as direct violence in injuring mechanism. Scores of examples of this might be cited. One will suffice. In a motor van a long horizontal rod was used to couple the steering gear to the leading wheels. The rod was broken solely by vibration. It was replaced by a much heavier and stronger bar. That was broken in much the same way, and finally guides had to be fitted to steady the rod and prevent it shaking."

Points on Spring Suspension.—As regards the suspension of springs of horse-drawn vehicles and automobiles, the careful observer will note one point of divergence at once. When elliptic, or semi-elliptic, springs of the ordinary description are used, he will see that in most light horse carriages only two are suspended, one over each of the axle shafts, across the width of the carriage. In automobiles of every build and motive power, while a single spring may be thus attached to the forward axle, the rear axle supports two, one at each side of the frame, and running in the length of the carriage. This is a construction found only in the heavier patterns of horse drawn carriages, and in both cases it is resorted to for the purpose of neutralizing the forward lunge of the body, inevitable on rough roads with a single transverse elliptical spring. With the horse carriage of the heavier pattern such vibration is annoying and also hurtful to the body, frame and springs. With the automobile, however, the case is even graver; for not only will similar results follow at high speed, but the proper distance between the motor, usually carried in the body above the springs, and the rear axle will be continually disturbed, with consequent damage to sprocket, chain and gears and loss of a steady drive. Thus, in carriages which have no other provision against this tendency of the rear axle to throw backward or forward under the stress of travel, it is necessary to use a device known as a distance rod to maintain a fixed distance between motor and drive axle, when the throw of the springs would otherwise permit it to be disturbed. The better method of overcoming this danger is to set the springs in the length of the carriage, as just described; for thus most of the violent jars in this direction are absorbed, and the fixed relation of motor and axle maintained, without rigid attachments, which would form

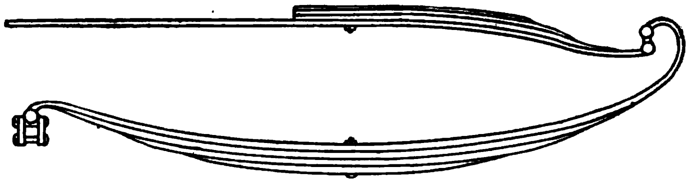


FIG. 75.—Scroll Bottom Carriage Spring, half elliptic, showing connections by links and shackles.

another notable occasion of accidents. This allows the springs to lengthen under pressure from above or from the direction of travel, and further reinforces against sidewise lunges, which, however, are of far less frequent occurrence. With the use of transversely arranged elliptical springs on both axles similarly troublesome conditions in the steering mechanism would result; the turning of the steering lever frequently compressing the spring sufficiently to make steering uncertain, and the numerous jars of the vehicle on a rough road or at high speed often tending to check its operation altogether.

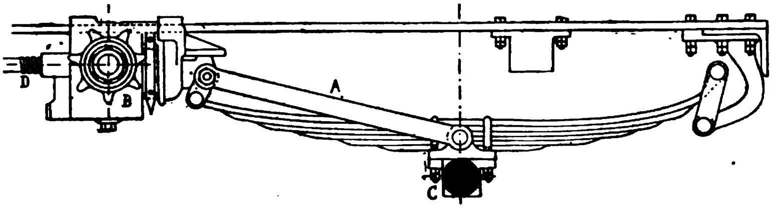


Fig. 76.—Spring and Radius Rod of the Mors Carriages. The rod, A, maintains a fixed distance between the sprocket pinion, B, and the wheel axle, C, even when the springs are constantly in action. This carriage also has a device for varying the distance between the countershaft at B, and the engine pulley, by sliding the entire shaft forward or back under impulse from the screw, D. The spring, being hung on links at front and rear, has considerable play, up and down, without disturbing the fixed relation of the axle, C, and the counter-shaft, B, as determined by the radius rod, A.

Dimensions of Springs.—Of the four varieties of springs used in vehicles of various kinds—extensible spiral, compressible spiral, coiled, and laminated leaf springs—the last-named has been found by all odds the most suitable for automobiles in point of easy riding, if in no others. Such springs, which are composed of a number of leaves or laminæ of steel, can be made in proportions suitable for light or heavy loads, by varying the size and number of the layers, without involving the jolts and vibrations inevitable in any but the heaviest structures of the other descriptions. However, apart from certain well ascertained figures on the static weight of the load and the size and tensile strength of the springs designed to carry it, there are no reliable data regarding the proper proportions of springs for automobile carriages. As we have said, this is, and must continue, a matter to be governed most largely by experiment, apart from mathematical calculations, since the constantly varying conditions of automobile travel preclude exact theory. Among these variants may be mentioned high speeds on any and every kind of road and the use of pneumatic tires. The matter is still further qualified by the size of the tires and the degree of inflation, for both of these points are important in modifying the stress to come upon the springs. Indeed, there is no more important factor in the high speed motor vehicles than the rubber tires, although the properties developed in its practical operation by no means permit its use on vehicles without suspension springs of some description.

The Effects of Pneumatic Tires.—The use of pneumatic tires on a vehicle permits the absorption of considerable vibration and the consequent use of softer springs than are possible with steel tires. One reason for this is that pneumatic tires, after violent or unusual compression, do not rebound, as even the best springs will do; whence only a minute portion of the total shock is transmitted from them to the springs. On the other hand, however, they have a certain bouncing motion of their own, which is imparted to the running gear, and will occasion an annoying back-jolt, unless suitable springs are interposed. This is entirely neutralized by the use of properly adjusted springs, although in the matter of adjustment we must consider the size and degree of inflation of the tires, the weight and dimensions of the springs, and the average speed used. In some respects a heavier spring gives easier riding than a light one, since the latter is apt to bounce disproportionately, even with good pneumatic tires, when the road is somewhat rough. In this matter some authorities make a direct comparison with the action of pneumatic tires on bicycles, whose ease of riding at high speeds has frequently been found to be a consideration not only of the road surface, but also of the degree of inflation of the tires. The severity and quality of the jars received under stated conditions is, therefore, typical in these particulars of the stress brought upon the springs set over the pneumatics in an automobile.

As the reader or any careful observer may readily conclude from the facts, pneumatic tires, if properly inflated, while a great factor in easy traction, are by no means the sole requirement. While they absorb much vibration unavoidable in steel-tired vehicles, without springs, they do not wholly set aside the rule that it is exceedingly bad construction not to suspend motors and other heavy freight. As has been frequently learned at considerable cost, rubber tires will not prevent broken axles when the motor is hung below the springs. For this reason many manufacturers use, not only additional springs for the seats, but also doubly suspend the moving parts, such as boilers and engines in steam carriages, or storage batteries in electric vehicles. Frequently, however, this additional precaution acts to neutralize the effect of the springs by aggravating jolts instead of allowing them to be properly absorbed as would otherwise happen.

The whole situation, as regards the relation of springs and pneumatic tires, may be understood by reference to common experience with bicycles. As is generally known, unless certain ascertained rules are observed regarding both the inflation of the tires and the method of riding, the rider is liable to experience a series of annoying jolts and vibrations on the best-made roads. Thus, while the rear, or drive-wheel tire, is usually inflated until very hard, the forward tire is allowed to remain considerably softer. By this means are avoided the vibrations which inevitably follow when both are pumped hard. The rider soon learns, also, in passing a street crossing or a hollow in the roadbed, to raise himself on the pedals, in order to escape a shock of considerable severity. To partly obviate this necessity and "make all roads smooth," several makes of bicycle have what the manufacturers call a "cushion frame," consisting of a flexible spiral

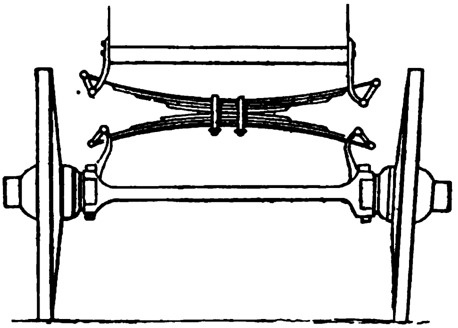


FIG. 77.—Forward Axle of the Jeanteaud Electric Carriage, showing double half elliptic springs with connections by links to frame and body.

spring inserted in the tubular support of the saddle post. The result is that the rider is greatly relieved of shocks and vibrations, the spring acting to absorb most of the bounding action of the tires. Nor has a similar result been otherwise successfully achieved, although it has been claimed by some bicyclists that the annoying jolts, due to a hard forward tire, are greatly reduced when a moderate load or a child is carried on the handle bars. Imperfect inflation of the rear tire is apt to strain and loosen the spokes, while only slightly modifying the annoying effects of travel on uneven roadways. The bearing on the situation of automobile construction is obvious. For, since the passengers cannot mitigate such shocks by any changes in position or distribution of the load, properly proportioned springs are the only resort.

Condition of Spring Dimensions.—In judging of the dimensions and elasticity of springs suitable for carriage use the limit of elasticity must be carefully considered with relation to the static and maximum loads to be carried by the vehicle. The static load is the dead weight of the vehicle body and frame, together with that of the passengers and other freight, estimated when at rest. The maximum load is the proportionately increased weight of the same items, with relation to the traction effort required when the vehicle is running at its highest speed, under test conditions as to road roughness or hill-climbing requirements. Similarly, the ultimate load is the greatest weight possibly carried with good spring action. That the springs should be calculated to retain the elasticity, or have the ultimate strength far beyond the maximum load, is obvious, when we consider the office of a spring in any aspect. In calculating the proportions of springs in the best constructed railroads, it is usually customary to consider the maximum load as twice the static load. Whence it is the general practice to estimate the fitness of a given spring for its work as equivalent to the quotient of the weight of the spring divided by the product of its length, between the extremities of the longest leaf, and the number, width and thickness of the other several leaves. The variable nature of carriage roads makes the proportion of static and maximum load much higher for horse-drawn vehicles than for railway cars, except where only the most moderate speeds are to be used, but for automobiles, always calculated for high speeds, it never falls below a ratio of 1 to 3, and is often estimated as high as 1 to 5. As has been pointed out by several authorities on the subject, the difficulty of obtaining springs for automobiles, which shall be serviceable under all conditions, is greatly aggravated when the weight of the body, motors, etc., is very much in excess of that of the passengers provided for. This is true, since a spring that will subserve the end of easy riding under usual conditions, with extra heavy accessories of this description, would permit no end of jolting and annoying vibration at high speeds on imperfect roads. The fault is difficult to discover except under test conditions. For this reason builders have frequently attempted to counteract the uncertainties of spring action by using extra springs on the seats, somewhat after the fashion of those used in some rough farm and draft carts, where no springs at all are used between the body and the axletrees.

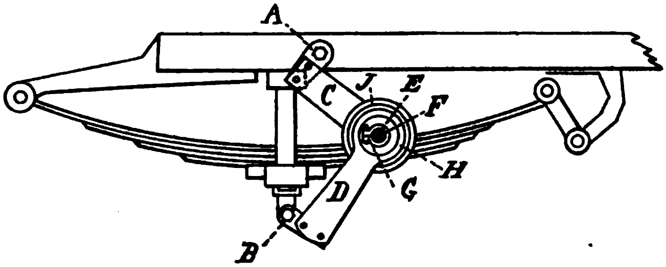


FIG. 78.—Jar-absorbing Spring Control Apparatus used on the Peugeot carriages. Here the arm, C, is jointed to A, which is pivoted to the frame above the spring as shown. Arm, D, is jointed to B, which is pivoted to the dead axle or sleeve below the spring. Both C and D work upon the common spindle, E, being secured in place by the nut, F, adjusted and secured in place by a bolt at G. A thick leather washer at J is placed between the disc, H, on the end of D, and a similar disc on the end of C, while the spindles of A and B move on thick leather collars; these three points of friction resistance serving to restrain and delay the tendency of the spring to resume its normal position after each depression, and thus absorbing the shocks of travel. In later forms of this apparatus a strong coiled spring is substituted for the leather washer at J; either device serving equally well to absorb jars and control the action of the springs, according to adjustment.

As a general rule, also, such seat springs modify the practical rules usually followed, permitting the use of even lighter springs to support the body. To sum up the general requirements in a few words, we may say that, while the pneumatic tires will often absorb vibrations, thus permitting soft and light springs under the body, the occasional inequalities in the road are apt to occasion a quick succession of annoying jolts, reaching by accumulated forces almost to the limit of spring elasticity, or succeeding one another so rapidly, at high speed, that the springs have little time to recover their normal shape. This seems to indicate that a heavier spring is preferable, or else that spring construction must be in some way varied to give firmer attachments and more evenly distributed elasticity; the time required by the spring to recover itself being the same under all conditions, some springs are thus unfit for high speed work. Many manufacturers prefer semi-elliptical springs to the full elliptical on the ground that their elasticity is greater for a given weight of spring, and the consensus of opinion on the latter is that the longer the spring, within reasonable limits, the greater the combined elasticity and lightness. When such springs are used as side supports it is general practice to attach one end direct to the longitudinal frame and connect the other by a link, thus allowing ample freedom toward lengthening. When placed transversely over the forward axle both ends are secured to links, the centre being securely clamped.

Attachments for Springs.—The ends of ready lengthening and extra elastic support are also accomplished by the use of what are known as scroll elliptics and semi-elliptics, wherein one leaf of the spring is extended somewhat at one end and turned over, like a rolled scroll, to be connected to its mate or to the carriage attachment by suitable links or other joint. Links are preferable in many places on account of the ready action allowed in several directions, without involving tendency to yield unduly under ordinary conditions. The high speed requirements of motor carriages makes it nearly imperative that leaf springs, either half or full elliptic, should be securely clamped to the supports by clips and nuts, rather than by bolts through bolt holes in the centre. This is true because such bolt holes are liable to prove a source of weakness under high speed conditions and to cause the breaking of springs at the very time when their full strength is most requisite. With clips this danger is wholly averted, and, instead of a weak point at the centre, an additional rigidity and re-enforcement is obtained.

One of the most efficient arrangements of springs for high speed carriages is that found in the Jeanteaud electric car and one or two motor carriages of American make. Two semi-elliptical leaf springs are clamped together at their centres, leaving the two extremities of the upper one in position for attachment to the carriage body, and the two extremities of the lower one in position for attachment to the axle. Links are then bolted at all four points in order to suspend the springs so as to permit the greatest freedom of motion laterally and allow for considerable compression.

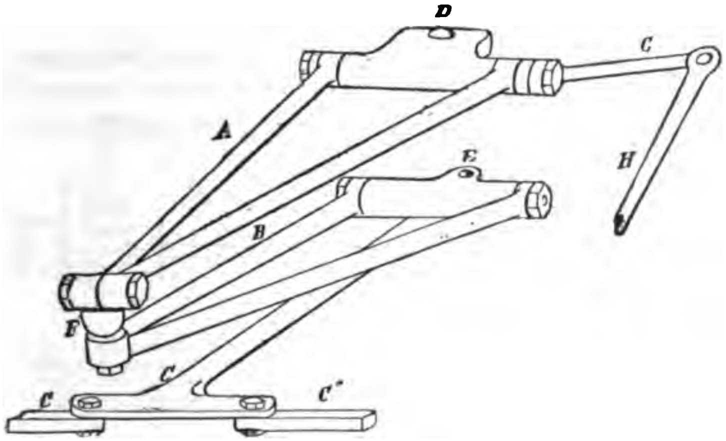


Fig. 79.—The De Dion & Bouton Spring Compensating Steering Device. The V-shaped piece A, constructed of two pieces, as shown, is attached to the tubular front cross-piece of the body frame at D, and pivoted on the ball joint at F, to the lower V-shaped piece, B. This is also pivoted at F, and is attached to the axletree at E. The T-piece, C, is also pivoted at E rigidly with B, so as to turn sideways with it. It carries the links C′ and C″, which actuate the steering arms of the two stud axles. The link, H, is attached to the arm, G, and when moved forward or back by the worm gear and pinion arrangement at the base of the steering-wheel pillar, moves the entire structure, A, B and C, on the pivots, D and E, to the right or left, as desired. The object of the device is to allow of a certain up and down movement, as the springs yield, without disarranging the steering gear or vibrating the steer wheel. In such cases the V-pieces, A and B, move on the ball joint F, thus permitting the points, D and E, to be approached and separated, as the springs move.

Construction of Springs.—The leaf springs used in road carriages and railroad cars consist of several layers of steel plates or leaves more often slightly bent, so that, when laid together, they are found forming superposed arcs of so many concentric circles. It is essential to a serviceable spring of this description that the line of the arc be carefully followed from end to end of each plate, and that no attempt be made to straighten or bend back the extremities of the longest leaves. This is true because the spring effect is derived from the temper of the metal in permitting the load to flatten all the arcs at once under a single stress, which involves that they should slide upon one another in altering their shape, as could not be the case were there any such departure from the line of the arc, as has been mentioned. In that case the several plates would tend to separate and "gape" under a load requiring a degree of compression tending to bring the extremity of any arc to the straight portion of the top leaves. The result would be a loss in spring action, and a probable source of breakage on occasion. In constructing laminated leaf springs it is essential that the plates should decrease on a regular scale of lengths, in order that the structure may be of equal strength throughout and of sufficient flexibility for the loads calculated to its dimensions. Where such a spring is thick, consisting of a number of plates, it is a good working rule that the ends of each several plates should touch the sides of a triangle, whose base is drawn between the extremities of the longest plate and whose apex is at or about the theoretical centre point of the spring's movement. This means that, with a well-proportioned spring in its normal shape, the end of each separate plate should be equidistant from that of the one immediately above it and of the one immediately below it. By this construction even distribution of stress is attained without waste or resistance from inactive

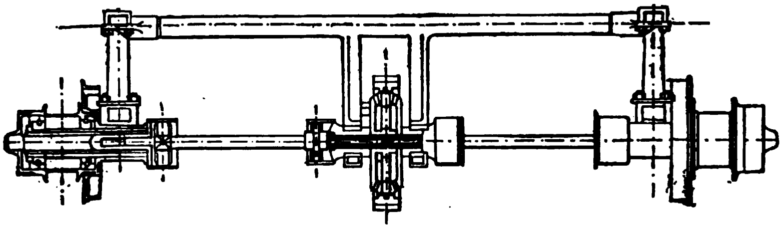


FIG. 80.—Jointed Rear Axle of the De Dion & Bouton Carriages. By the use of universal joints between the driving spur and wheel spindles a steady drive may be maintained between the spur, hung on the body, above the springs, and the wheels, below the springs, even on the roughest roads, when the springs are constantly in action.

portions of the length of each plate, as would be the case in a laminated spring flattened at the top plate and having the longitudinal profile shaped to an arc. Such a spring, however, would embody bad construction in another particular, since it would neglect one very essential feature of spring construction—curvature of the plates. This curvature is intended to represent the difference between the spring under static and maximum load; at the latter point its leaves should be nearly straightened under stress; beyond that point, as they are bent backward and downward, the point of ultimate strength, involving loss of elasticity and breakage, is rapidly approached. It follows, therefore, that the end of a perfectly elastic and serviceable spring is best attained by such curvature as will allow bending of the plates from each extremity of the top plates, on the support at the centre, without involving endwise compression, as is the case when the curve approaches a semi-circular contour. Consequently, laminated leaf springs, as a usual thing, are constructed to an arc of never more than ninety degrees and often very much less.

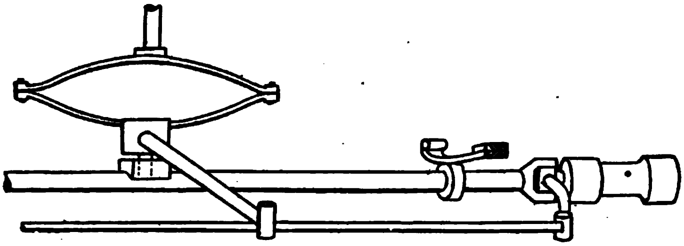


FIG. 81.—Spring Compensating Steering Device used on the Oldsmobile Carriage. The cut shows the spindle of the steering lever with its attached arm joining the transverse link at about the centre of its length. The attachment of one of the side springs is shown near the right-hand end of the axle. The small elliptical spring takes up and absorbs the vibrations of travel, rendering steering positive and uninterrupted.

Rules for Calculating Springs.—Although as a general proposition, the usefulness of a spring for given work and load is strictly a consideration of the total length of the structure between points of attachment, the thickness and number of the leaves, and the quality of the steel used—the last-named consideration is of the utmost importance—there are certain formulæ followed in railroad work, and to a certain extent, in carriage designing, that are useful to the practical automobile builder. As given in several works on locomotive and car construction, they may be summarized as follows:

Let B represent the breadth of the plates in inches.

Let T represent the thickness of each in sixteenths of an inch.

Let N represent the number of plates in the spring.

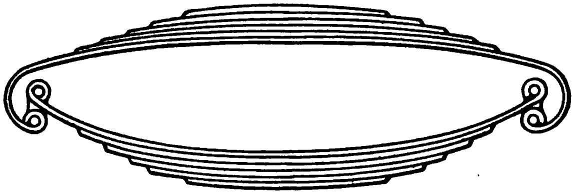


FIG. 82.—Rear Spring used on the Packard Light Car. The C-shaped upper portion is connected by shackles to the elliptical lower half, the effect being to allow the use of fixed distance rods and keep the chain taut, without the use of the usual devices of foreign and American carriages.

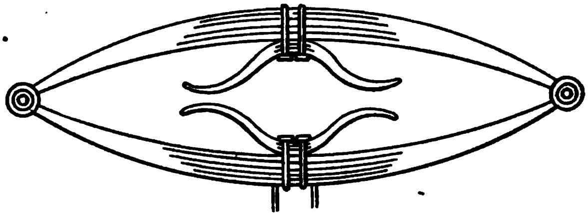


FIG. 82a.—Compound Check-spring Device of the Mercedes Car. The small laminated check-springs within the elliptical structure absorb all extraordinary jars and prevent too great distention under load.

Let S represent the working span, or the distance between the centres of the spring hangers, when the spring is loaded.

Let W represent the working strength of a given spring.

Let E represent the elasticity of the spring in inches per ton.

The elasticity or deflection of a given spring is found by the following formula:

$$1.66 \frac{S^3}{NBT^3} = E \text{ in 16th inch per ton load.}$$

The span length due to a given elasticity and number and size of plates is as follows:

$$\sqrt[3]{\frac{EBNT^3}{1.66}} = S \text{ in inches.}$$

The number of plates due to a given elasticity, span and size of plates:

$$\frac{S^3 \times 1.66}{EBT^3} = N$$

The working strength, or greatest weight a spring can bear, is determined as follows:

$$\frac{BT^2N}{11.3\,S} = W \text{ in tons (2,240 lbs.) burden.}$$

The span due to a given strength and number and size of plates:

$$\frac{BT^2N}{11.3\,W} = S \text{ in inches.}$$

The number of plates due to a given strength, span and size of plates:

$$\frac{11.3\,W\,S}{BT^2} = N.$$

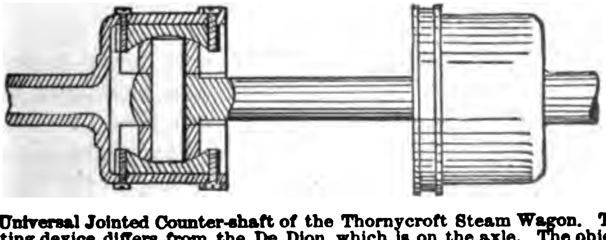


FIG. 88.—Universal Jointed Counter-shaft of the Thornycroft Steam Wagon. This compensating device differs from the De Dion, which is on the axle. The object is the same, to permit of an uninterrupted drive under rise and fall of springs.

CHAPTER EIGHT.

MOTOR CARRIAGE WHEELS.

Requirements in Motor Carriage Wheels.— As summed up by a noted authority on the subject, vehicle wheels must have three qualities of construction: (1) They must be sufficiently strong for the load they are to carry, and for the kind of roads on which they are to run. (2) They must be elastic, or so constructed that the several parts—hub, spokes and felloes, or rim—are susceptible of a certain flexibility in their fixed relations; thus neutralizing much vibration, and allowing the vehicle greater freedom of movement, particularly on short curves and when encountering obstacles. (3) They must, furthermore, be sufficiently light to avoid absorbing unnecessary power in moving. In addition to these qualifications, wheels suitable for automobiles must be able to resist the torsion of the motor, which always tends to produce a tangential strain. This is the reason why tangent suspended wire wheels are invariably used in automobiles, instead of the other variety, having radially-arranged spokes. They must also have sufficient adhesion to drive ahead without unduly absorbing power in overcoming the tendency to slip on an imperfectly resistant road-bed. The importance of the two last considerations may be readily understood in view of the fact that the wheels of motor carriages receive the driving power direct, instead of being merely rotating supports, like the wheels of vehicles propelled by an outside tractive force.

Methods of Constructing Wheels. — In order to meet the conditions above mentioned various devices have been resorted to. Where wooden wheels are used in any kind of vehicle, the effect of elasticity is very greatly increased by "dishing"; that is, by inclining the spokes from the exterior plane of the rim to the centre point of the axle spindle, so as to make the wheel a kind of flattened cone. This construction has the effect of transforming the spokes into so many springs, possessing elastic properties, and renders the wheel capable of being deformed under sideways stress. The shocks of collision with obstacles are thus distributed through the flexibly connected parts, as could not be the case if the wheel were made in one piece or on one plane, and the consequent wear and strain is greatly reduced. The dish of the wheels is usually balanced by slightly inclining the axle spindle from its centre line, thus bringing the lowest spoke to a nearly vertical position with relation to the ground. A great resisting power to shocks produced by obstacles such as is afforded by dished wheels is of far less importance in vehicles designed for good roads, as are most automobiles, which need only such inclination of the spokes as will provide for the even distribution of shocks, and the maintenance of uniformity in pressure.

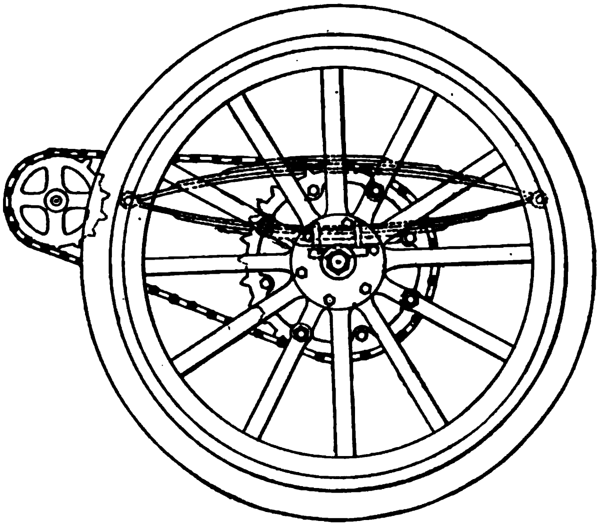


FIG. 84.—Wooden Wheel, such as is used on heavy gasoline carriages of Panhard, Mers and others. It turns loose on the axle and is driven by a sprocket on a counter-shaft.

Advantages Attained by Dishing.—The significance of the word "dish" is obvious, when we consider that it indicates a diametrical section of about the shape of a saucer or shallow dish. While, as we have seen, this shape furnishes a very desirable spring effect against sidewise strains and shocks, such as are met in swinging around a corner or sliding against a curb—since, although a wheel is always weakest sidewise, it is difficult to thrust a cone inside out—there are several constructional considerations that render it a desirable feature for wagons of all descriptions. The first of these has reference to maintaining a balanced hang to the wheel. Under the conditions of travel a wheel acquires the tendency to crowd on or off the spindle, with the result that it eventually wears loose, as may be frequently found particularly on heavy carts. Since the spindle is tapered it is necessary that its outer centre should be lower than the inner, and, then, in order to counteract the outward inclination of the wheel, and consequent tendency to roll outwardly, the spindle end must be also carried forward sufficiently to make the wheel "gather," which is to say, follow the track. A moderate dish contributes to the end of bringing the tire square to the ground, while at the same time enabling the wheel to rotate without undue wear at the axle. Another constructional advantage involved in the dishing of wooden wheels relates to the method of shrinking on the iron tire. As is known, the tire is first forged to as nearly the required diameter as possible, after which it is heated, so as to cause it to enlarge its diameter and in this state placed about the rim of the wheel. When once more cooled it fits tightly. As frequently happens, however, a tire is made somewhat too small for a wheel, which involves that, in the act of shrinking, it will either force the wheel into a polygonal shape or crush one or more of the spokes. By giving the wheel a dish, the shrinkage of the tires merely increases the inclination of the cone from base to apex, the spring of the spokes being quite immaterial, all suffering to about the same extent.

Wooden Wheels and Wire Wheels.—There are two varieties of construction used in automobiles: the one following the theory of the horse-drawn vehicle, with wrought frame and wooden wheels; the other following the construction of foot-propelled bicycles and tricycles, with tubular frame and wire wheels. However, wire wheels are used on any kind of vehicle, and, following on the practices of the early makers of motor carriages, have gained wide recognition as the typical construction for this purpose. The principal argument for their use is the combination of lightness and strength such as no wooden wheel can attain. But they lack elasticity and without pneumatic tires are useless for automobiles. Indeed, it seems to be the conclusion of some authorities that the consideration of combined lightness and strength, urged alike for wire wheels and tubular frames, and perfectly proper in the case of bicycles, is of the nature of a superstition, which is hostile to the most advantageous progress in automobile construction.

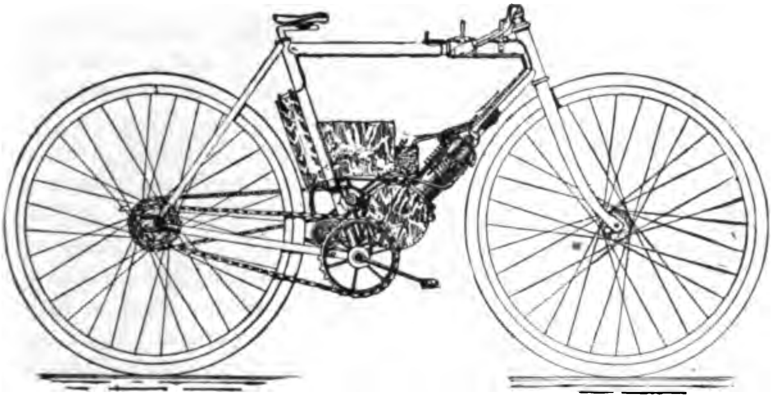


FIG. 85.—A Thomas Motor Bicycle, showing light tangent-spoke wire wheels and one style of mounting the motor.

Relative Merits of Wheels.—In order to briefly state the issues involved in the case of wooden wheels against wire wheels, we may say that the main requirements in any wheel are, not only its ability to sustain a considerable weight in its plane, but also its power to resist sidewise strains. Now, while it is widely conceded that a wire wheel will sustain a greater load than a wood wheel, the two being considered weight for weight, it certainly will not sustain as great a strain sideways, which represents the line of the wheel's greatest weakness. A wire wheel driven against a curb with sufficient force will have its rim dented, with the result of loosening all its spokes and ruining it. A wooden wheel, on the other hand, may have a gap in it and still be serviceable. It may even run with one or several spokes broken off. A wire wheel being suspended on its spokes—the load being hung between the hub and the perimeter—is bound to suffer in proportion to the number of points of suspension lost. A wooden wheel, being supported at both hub and perimeter by its spokes, has a certain power of compensating or distributing the strain, so that, while a deficiency of support is no advantage, it does not always involve destruction.

Disadvantages of Light Construction.—On the point of using tubular frames, C. E. Woods asserts that for an electric cab weighing 4,900 pounds only 200 pounds is saved, while the total strength is no greater than with wrought bar frames of suitable dimensions. Moreover, he alleges, that tubing is a positive detriment from the fact that ordinary blacksmiths and wagonwrights cannot repair it, and, consequently, that in case of accident one must always resort to the manufacturer. A similar line of reasoning is applicable to wire wheels, which involve the danger of crystallizing the wires by unequal strain or adjustment; of crushing the rim, by running on a deflated tire; or, of "buckling" the spokes by collision with a curb-stone or another vehicle, always with the result that others than road-side smiths must be called on for repairs. The sum of Mr. Woods' argument is that only such constructions should be used as may be everywhere readily handled by skilled mechanics.

The Use of Wood Wheels.—Mr. Charles E. Duryea, in a letter to the "Horseless Age," argues ably for the use of wooden wheels, with the following statements of advantage: (1) The construction, proportions and strength suitable for given requirements have been carefully determined by years of practical experience. (2) Being practically one piece, they do not deteriorate by usage in bad weather and are readily cleaned. (3) If broken, they may be anywhere repaired, all the parts being easily obtainable. (4) They will often give good service even in a badly damaged condition. (5) Experience has shown that they are far more elastic than wire wheels. (6) In wire wheels any attempt to make the hub of proper length to give spread to the spokes under strain results in a clumsy appearance. (7) If the spokes are proportionately strengthened the wire wheel becomes heavier than the wood wheel. (8) The greater number of spokes in a wire wheel, and their proximity at the hub, where dirt and moisture are collected, prevents easy cleaning and promotes rust. On the point of elasticity Mr. Duryea says: "As a matter of fact, the wood wheel is far more elastic than the steel wheel, as may be readily seen by watching a light buggy drive over car tracks or rough pavements. The rims of the wheels vibrate sideways, sometimes as much as two inches, without damage to the wheel or axle, on which account fewer broken axles will be had when wood wheels are used instead of wire ones. While it is true that the pneumatic tire practically removes the necessity of an elastic wheel, there is no need of refusing to accept a valuable feature." On the wagons manufactured by Mr. Duryea's company wooden wheels with pneumatic tires are used with excellent results. His opinions on the subject seem to be shared by a goodly number of motor carriage manufacturers, notably Haynes-Apperson, the New York Electric Cab Co., and the Autocar Co., all of whom are now using wood wheels most largely, if not exclusively.

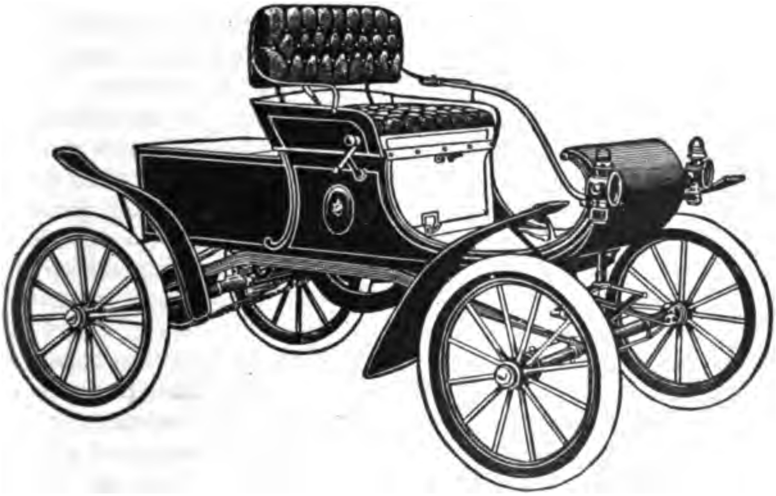


FIG. 86.—Oldsmobile Runabout with wooden wheels.

Dimensions of Automobile Wheels.—The consideration of wheel dimensions is important in automobiles, and in no other particular is it more essential that the relations of size and use be accurately calculated. In horse-drawn vehicles the forward wheels are made of smaller diameter, in order to allow them to cut under the body in turning. This consideration precludes the possibility of making the diameter sufficiently large to ensure all-around easy running, except by the use of high frames or long axle shafts. In automobiles, on the other hand, the forward wheels may be of any convenient diameter; since by the use of knuckle-jointed steering axles a wide angle of turning may be obtained without using a pivoted axle shaft. As a general proposition we may assert that the larger the wheel the smaller the shocks experienced in passing over inequalities in the road bed, and the smaller the buffing qualities required in the tires. Thus it is that a wheel five feet in diameter will sink only one-half inch in a rut one foot wide, while a thirty-inch wheel will sink nearly three times as deep, with the result that the resiliency of its tires must be enormously larger, in order to compensate the greater shock experienced. The larger wheel also rises less quickly over obstructions. These are considerations of great importance in motor vehicles, in which any device for the reduction of vibration and concussion is desirable. Furthermore, when a wheel is properly tired, the road resistance to its steady and even rotation is decreased as the square of the increase in its diameter, such a wheel of sixty inches diameter decreasing the resistance in a ratio of between 50 per cent. and 70 per cent, as compared with a wheel of thirty inches diameter. There are, however, other methods for neutralizing the shocks on rough roads. For, as experience has demonstrated, the end of obtaining a low and easy-running rig may be achieved quite as well by increasing the width of the vehicle, the length of the springs and the size of the tires, as by adding to the height above the ground. By following this theory of construction, the Duryea Power Co. is able to use wheels of thirty-inch and thirty-six-inch diameter for the front and rear wheels, respectively, and secure a remarkably easy-running carriage. They are adopting, however, a construction which is, in correct proportions, very nearly equivalent to large diameter—the use of broad tires. For, as has been repeatedly demonstrated, the broad tire is superior to the narrow one in the very same particular, that it will not sink so quickly into mud and sand, and, by its greater buffing properties, neutralizes the concussion otherwise experienced with small wheels. Their thirty-eight-inch springs are another potent factor in achieving the desired end.

Practical Points on Wheel Diameter.—While it is no part of the province of this book to reproduce the lengthy and elaborate calculations by which the fitness of wheels of given diameters, breadth of tire and material of construction is to be determined, we may briefly indicate a few of the leading considerations which have moved manufacturers in general to regulate themselves on these points. It is a distinct advantage to enlarge the diameter of motor carriage wheels for the purposes of obtaining an offset to the concussions experienced on rough roads, to obtain higher speed, within certain limits, and to secure greater durability for the tires. The last consideration is of great importance, particularly when hard rubber tires are used. The principles involved are well set forth in a recent article in the "Horseless Age," which contains the following statements: "To prevent traveling on the rim a tire should bind the whole surface of the rim. The higher

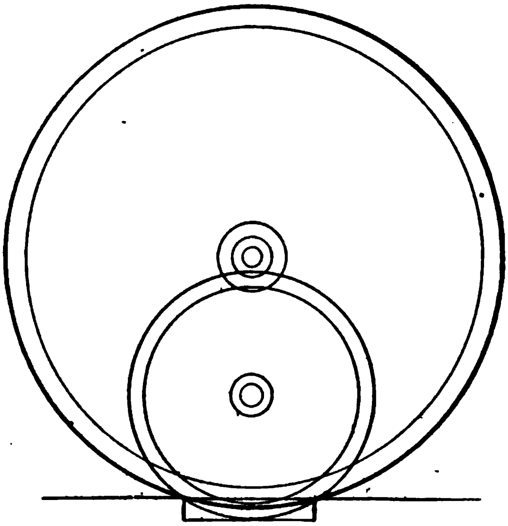


FIG. 87.—Diagram showing the relative drop into a road rut between a small carriage wheel and one twice its diameter.

the wheel the more adhesive surface there is for the tire. When the tire is bound in by lugs the natural kneading and straining of it between the lugs will in time either shear off the lugs or loosen them. Another reason why a large wheel is to be preferred from a tire-maker's point of view is that a large wheel does not turn round so many times in a given distance, and consequently does not wear the tire so fast. If a tire travels very fast under a heavy load the kneading of it causes heating and cracking, which are intensified on the small wheel. Our experience has proved that a large wheel greatly reduces the above difficulties."

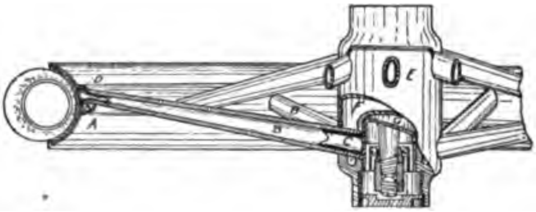


FIG. 88.—Part Sectional View of a Tubular Steel Wheel, used on many automobiles of all powers. Although, to the date of the present writing, the principal issue among authorities is upon the respective merits of wood and wire wheels, this type of wheel is steadily growing in favor. Among the advantages claimed are: superior strength to either wire or wood; true, balanced running, as a pulley on a shaft; practical immunity from dishing or crushing with the hardest use, or in ordinary accidents; immunity to rust, on account of the inner and outer brass coating on hubs and spokes and the brazing at all joints; ability to stand the twist and tension of severe strains in the transmission of power; rims formed from a continuous tube; spokes made from high carbon cycle tubing, oval in shape and reinforced at both hub and rim; perfect alignment secured by assembling all parts in jigs. As shown in the cut, the parts are: A, tubular steel rim; B, tubular steel spokes; C, tubular steel reinforcement at hub; D, tubular steel reinforcement at rim; E, outer tubular steel hub shell; F, middle tubular steel hub shell; G, inner hub shell over axle spindle. The method of securing the hub to the axle is also shown. Although, as must be fairly obvious, such a construction admits of very little sidewise spring action under stress of travel or collision, which is a particularly desirable feature in wooden wheels, especially with steel tires, the slant of the spokes effectually prevents such extreme deformation as would tend to disable a wood or wire wheel. The oval shape of the spoke tubes, and their arrangement as regards both hub and rim, enable the carrying of greater loads, in proportion to weight, than are possible with other varieties of wheel. It is also possible to keep such wheels perfectly clean, without risk of injury by rust, as must result from attempts to wash wire wheels, as already stated. Furthermore, tubular steel wheels do not shrink when dry, as do wooden wheels, and, consequently, require no process of soaking to restore them to normal condition.

Troubles with Large Wheels.—As against the above advantages involved in the use of large wheels, there are a number of objections of equal, if not greater, importance. Among these may be mentioned the fact that, the larger the wheel, the greater must be its proportional strength and weight of construction, in order to neutralize the ill effects of torsional motor effort, and

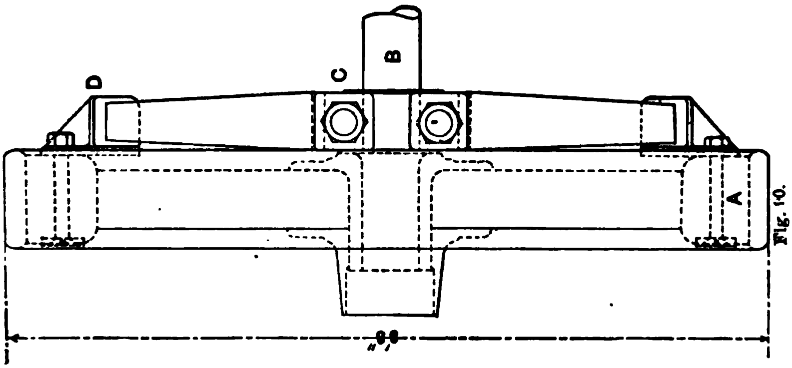


Fig. 90.

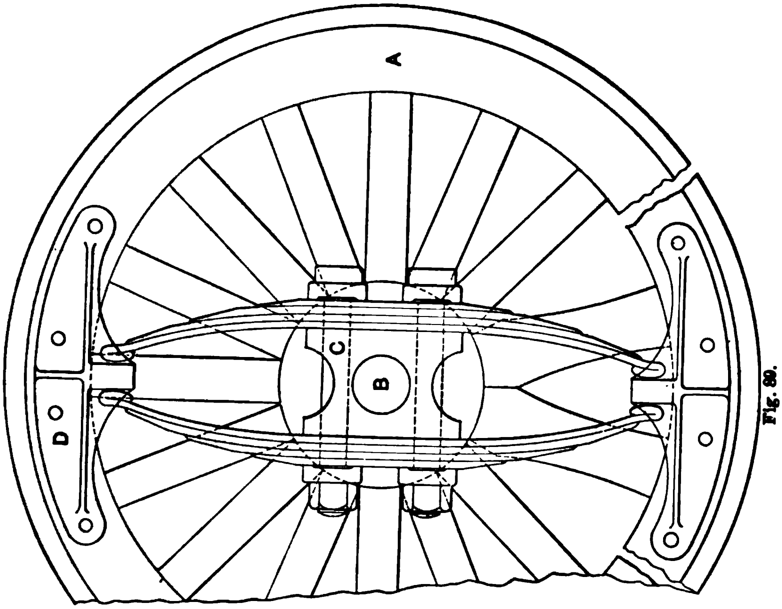


Fig. 89.

Figs. 89 and 90.—Two views of the Thornycroft Spring Drive Wheel. A is the felloe of the wheel carrying the iron tire. B is the revolving axle, which is independent of the wheel except for the springs secured to it by the bolts, C. D is the angle piece at the felloe carrying the lug to engage the springs, as shown.

disproportionate road resistance. Indeed, a moment's reflection will show that a wheel of sixty-inch diameter, built on the same dimensions of hub, spokes and felloes, as a wheel of thirty-inch diameter will possess considerably more than twice the liability to strain and breakage from the causes above named. If we may assert that such increased liability, as compared with the increase of diameter is on a ratio of three to two, it is obvious that a wheel of sixty-inch diameter must be very nearly three times as heavily and strongly built as a wheel of thirty-inch diameter, in order to insure its durability. We may readily judge, then, at about what point of increased diameter a light pleasure carriage would be equipped with cart wheels. This is only one of the numerous difficulties involved in attempting to use large wheels with a modern high-speed motor.

Thornycroft's Spring Drive Wheel.—A driving wheel much like those of the Hancock and Gurney carriages is used on the steam road wagons manufactured in England and America, under the patents of John I. Thornycroft. This device, which is shown in detail in the accompanying figures, consists of two oppositely attached leaf springs bolted rigidly to the end of the rotating rear axle, and following its motions. Immediately in front of these springs is the conical axle spindle, and when the wheel is set the leaf springs engage lugs on the angle pieces bolted to the felloes. The result is that the motive power is transmitted solely through the springs bearing on the lugs, which affords an exceedingly elastic connection on the very circumference of the wheel. Thus reducing the motor strain to the lowest point, it relieves the spokes of all strain beyond the dead load carried on the wagon. In the construction of wheels for this purpose, Thornycroft follows Hancock's wedge model, but utilizes the involved strength and solidity far more effectively. Similarly constructed wheels have long been used on the Huber traction engines with good results, the claim being that the yield of the spring permits the engine to keep moving until the wheel is forced over an obstacle in the roadway.

CHAPTER NINE.

SOLID RUBBER TIRES.

The Question of Tires.—All automobiles and cycles, and a large number of horse-drawn vehicles, use rubber tires. The object is twofold: first, to secure a desirable spring effect; second, to obtain the requisite adhesion to the road. While, with properly constructed springs, the first result may be achieved with steel tires, the second is almost impracticable when the power is applied direct to the wheel. Thus, if a light automobile be equipped with steel tires, the wheels will not drive on an imperfectly resistant roadbed, unless most of the load be placed over the rear axle, which, when it is too great in proportion, involves the disadvantage, that the steering will be unreliable, the forward wheels tending to skid, instead of turning the vehicle in a positive manner. It is not always practicable to remedy this difficulty, either by strewing sand in front of the wheels or by applying power to all of them. An attempt to produce adhesion by constructing tires with teeth or corrugations, or by giving them extra breadth, would increase the weight for only temporary advantage. The simplest and readiest resort is found in the use of rubber tires.

The Reduction of Vibration.—On the point of reduced vibration in a vehicle, as it is related to the kind of tires used, W. Worby Beaumont says: "It must also be remembered that the greater comfort of the rider is due to lessened severity of vibration and shock, and this is a relief in which everything above the tires participates. Now, this means a reduction in the wear and tear of every part of the car and motor which can easily be underestimated. The experience of the London cab-owners, whose records of every cost are carefully kept, is a proof of this; and they find that rubber-tired wheels suffer very much less than the iron-tired, every part that could be loosened or broken by constant severe dither or hard vibration remains tight very much longer, the breakage of lamp brackets, hangers and other parts does not occur, and that even the varnish, which being hard and breakable, lasts a great deal longer. The same immunity of the high-speed car is obtained by pneumatics, as compared with solids, and its value is greater in proportion to the greater value of the vehicle." It may be readily understood that, if such a consideration is of importance in horse-drawn vehicles, it is even more so in the case of automobiles, whose parts are subjected to strain both in traveling on rough roads and also from the vibration of their own motors. This is particularly true of carriages driven by gasoline engines, in some makes of which the vibration is often excessive, generally increasing in direct ratio to the speed at which the carriage is propelled. Hence, without some kind of buffing properties at the tires, disaster must soon follow.

Rubber Tires for Automobiles.—There are two varieties of rubber tire in use for every kind of vehicle except cycles; the solid tire and the pneumatic, or inflatable tire. As is generally known, the pneumatic tire was first devised in order to furnish the needed resiliency in bicycles, and for the same purpose it has been found useful in automobiles, particularly in connection with wire wheels. It has, however, one notable disadvantage—the constant liability to puncture—with the consequent danger of being made useless. In order to remedy this defect inventors and manufacturers have introduced such features as thickening the tread of the tire, increasing its resistance to puncture by inserting layers of tough fabric in the rubber walls, and even using small metal scales.

Merits of Solid Tires. — From the standpoint of durability solid tires are the best beyond question, not only for heavy service, but also for high-speed light cars. The combined effects of speed and weight work less rapidly upon them, enabling a greater mileage endurance than with the best pneumatics. Indeed, it is the verdict of very many authorities that the lowest mileage records have been obtained with the use of high-priced pneumatics. Such tires, however, contributing a greater ease of travel in most of the ordinary designs of racing vehicles, are used by persons eminently well able to afford the involved additional expense. Consequently, the relative merits of the extremes are quite immaterial to the general public. Commenting on the statements of a writer who contended that the question of tires suitable for various kinds of vehicles is largely an open one, Mr. C. E. Woods writes as follows: "The writer's own experience has been very different in its results. . . . After the construction of a few vehicles, early in his development of them, on which he went through the same experience indicated by Mr. Condict's article, he adopted the hard or solid rubber exclusively, and designed diameters of wheels, width of felloes, etc., to accommodate such sizes of tires as by experience proved best suited to the many and different styles of vehicles to be built. For he had discovered that the resiliency of pneumatic tires was entirely lost

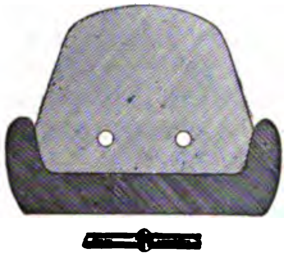


Fig. 91.

Fig. 92.

Fig. 93.

Figs. 91, 92 and 93.—Three varieties of Solid Rubber Tire, showing shape and methods of attaching on the rims. Fig. 91 shows a broad tire, which is attached by forcing over the edges of the channel-shaped rim, to which it is vulcanized, and also secured by endless wires, welded, as shown. Fig. 92 shows a tire secured by bolts through the base, also by annular lugs on the rim sides fitting into channels. Fig. 93 shows an attachment made by connecting at the base by a peripheral T-piece, also by bolts securing sides of channel-shaped rim. All three varieties show rim channels, so shaped as to allow of considerable distortion, laterally, under load.

when the carriage was properly designed and the weights properly distributed on its points of support, and the latter placed on properly designed springs. The easy-riding carriage for any purpose depends entirely upon its springs for this qualification, and there is no reason why the automobile, with its heavier weight, should be any exception to the general rule. If, however, carriage design embodies the placing of a set of batteries (in electric vehicles) over one set of springs, making a very unequal distribution of the load—which in itself is always a faulty design—it cannot be expected to be easy, and a very large and not too much inflated pneumatic tire may help the difficulty a little. But even then when tires are inflated to the pressure necessary to give an economical power effect, there is scarcely any more resiliency left in them than that given by a hard rubber tire, and their unsightly and objectionable appearance, as applied to a general carriage production, is too well known to need comment here."

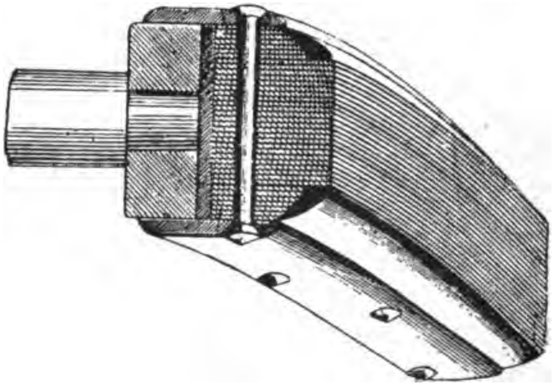


FIG. 94.—Indurated Fabric Solid Tire. This tire is constructed, so as to prevent rents and cuts across the tread, by inserting strips of tough fabric around the perimeter, so that the edges are brought into contact with the ground. Where clear rubber would yield, the fabric holds secure. The tire is attached by bolts through the base, as shown.

Comparative Values of Tires.—On the points here made, Mr. Woods seems to have the support of several experts in the matter of tires, although there is a widespread agreement that pneumatics are the only suitable ones for high-speed, high-power vehicles. Mr. Beaumont writes as follows: "For high-speed running with comfort over street crossings and level railway crossings, the expensive pneumatic is necessary, but it is a high price to pay for this luxury, and it will only be paid by the few who will pay anything for speed. After a while, when automobile travel settles down to the moderate speeds of the majority, and to the requirements of business, the better forms of solid or nearly solid tire, in which a comparatively small amount of internal movement of the rubber takes place, will probably be most used. A hard pneumatic tire is superior to this for ease at the bad places in roads and over crossings, but greater strength of material suitable for the purpose than is yet available is required to meet all the conditions."

FIG. 95.—Solid Rubber "Sectional Tire," having the tread divided into a number of toothlike sections, all attached in one piece to the rubber base, as shown, in order to give greater distortion endwise under load, thus allowing of considerable cushion effect. It has been claimed that the construction permits of real resiliency.

Durability of Solid Tires.—From the standpoint of lessening the vibration of running, and thus preventing considerable damage to the vehicle, Mr. Beaumont concedes that pneumatic tires are preferable, although, from considerations of durability, he prefers the solids. As to the life-period of solid tires, under constant use, he says: "With regard to solid tires, the experience of the London hansom cabs is of much interest. A pair of 1⅝ or 1¾ inch tires will last from a little over six months to, at most, nine months. The most rapid wear is on those cabs which have the best and fastest horses, if we except those cabs that have constantly to run in districts where the road surfaces are destroyed by the prevalence of tramways, those expensive metallic admissions of the badness of the ordinary roads, and of the incompetence and penny-wise policy of most of the road authorities. If thirty miles per day for the hansom driven by men who are, as most are, allowed two horses per day, and assuming 300 days per year, then a year's mileage would be 9,000. They run, however, not more than eight months at best before tire renewal, so that the mileage is not probably more than about 5,500 to 6,000. . . . The mileage of the tires on the four-wheel cabs is much greater, as would be expected, from the smaller weight each wheel carries and the lower speed. The miles traveled per month will also be less."

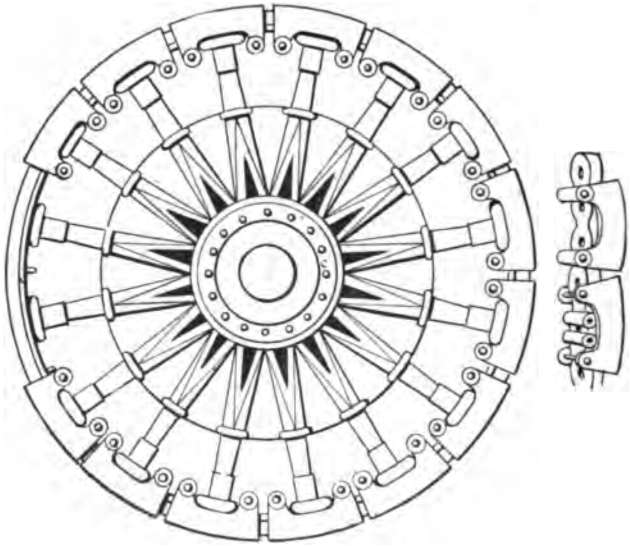


FIG. 96.—Wheel of the "Lifu" Steam Truck, showing a solid rubber cushion tire secured in position and protected by metal shoes around the rim. Although the attachment is so rigid as to prevent creeping, a very effective spring effect is obtained by combination of the cushion tire and shoes. It is effective for heavy service, which would soon destroy an ordinary solid tire.

Structural Requirements in Solid Tires.—The shape and methods of attaching solid tires to the wheel rims must both be determined with reference to the source and pull of the strains likely to affect them. The weight of the vehicle is nearly the greatest source of wear, but even this consideration is closely rivaled by the torsional strain from the engine and in braking, particularly in view of the almost universal use of comparatively small wheels. Indeed, no part of the wheel could suffer greater strain than the tire from the condition last mentioned. In view of the properties of rubber it may be readily seen that increasing the thickness of the solid tire, in proportion to the increased weight of the vehicle, will largely neutralize the destructive effects due to every cause involved in the structure of the running gear and its load. By this means is obtained a greater width of tread, with a probably smaller total abrasion of the surface from contact with the road bed, and a greater opportunity for distributing and neutralizing the harmful strains.

The tendency in solid tires is that cuts, due to stones or other sharp obstacles, tend to spread to the centre of the tire across the tread. This is due to the quality of the strains transmitted from the wheels, as above noted, and, in order to prevent this tendency from destroying the tire it is necessary to vary the shape. Accordingly, tires are made with bevel edges, rather than on square lines, and the profile is slightly rounded. This conformation, together with good width at the rim, is able to provide for absorbing much of the surplus vibration, while decreasing the ill effects due to the combined action of a heavy load and road resistance. On the whole it greatly prolongs the life of the tire. The curved surface at the tread and the bevel edges, tending to flatten under the load, provide a sufficient width to ensure good adhesion and the other advantages belonging to a wide tire, while, at the same time, reducing to the minimum the tendency to spread tears and cuts, as above mentioned.

Methods of Attaching Solid Tires.— There are several methods of attaching solid tires to the rims, as is shown by the accompanying figures. In these typical structures the rim carries flanges at either side to retain the tire, or else these flange pieces are bolted to the felloes. The tire is also retained in place, either by a suitable shaped T-piece running around the circumference of the rim, by wires drawn up to the proper tension and electrically welded at the ends, or is simply vulcanized to the rim. The last-named method of attachment is recommended by several writers on the subject.

CHAPTER TEN.

THE USE AND EFFECT OF PNEUMATIC TIRES.

Advantages of Pneumatic Tires.—As against the opinion of Mr. Woods, that the solid tire is preferable for all types and weights of motor vehicles, most authorities still maintain that the numerous advantages gained in the use of pneumatics cannot be dispensed with in automobiles, nor obtained by the use of any other devices. One very valuable quality of a pneumatic tire is its resiliency, or the ability to bounce in the act of regaining its normal shape after encountering an obstacle in the road. On encountering such a small obstacle as a stone, a pneumatic tire will yield to a certain extent, absorbing or "swallowing it up," at the same time exerting a pressure sufficient to restore its normal shape after passing the obstruction. This quality begets two advantages for easy driving: It does away with much of the lifting up of the wheel in passing over obstacles, which is otherwise inevitable, and also enables the tire to obtain a better grip on the road bed. Commensurate advantages are also derived from this cushioning quality in colliding with obstacles to one side or other of the tread; whence the total pressure exerted through the spokes is greatly reduced and such obstructions exert only a fraction of their usual power to retard the easy and steady operation of the motor and steering gear. In both cases, also, a large part of the shocks and vibrations, usually transmitted direct to the springs, are completely absorbed. No solid tires could furnish anything like such advantages in operation; the usual result, even with the most flexible springs, being that the motor is much shaken or damaged, or its action largely impaired. This is particularly true of the use of solid tires on electric vehicles, the damage resulting, both in point of efficiency and durability, having been estimated by several authorities as high as 30 per cent. As against this estimate we have the above quoted experience of Mr. Woods, himself an expert and manufacturer of electric vehicles. But that it is possible to supplement to a degree the imperfect cushion qualities of solid rubber tires, by the use of well-suspended springs, seems to be suggested by the report on another American make of electromobile, as published in the "Horseless Age." The writer there states: "The springs used on this machine were extremely flexible, so much so that the solid tires were extremely small, and the writer understands that the company intends to use steel tires next year." No data, however, are accessible on the durability of the motors used, nor on the behavior of this exceptional machine on rough roadways.

Speeding Qualities of Pneumatic Tires.—As has been already suggested by several quotations, the peculiar properties of pneumatic tires are nowhere of greater advantage than under high speed conditions. Since speed is one of the principal considerations with both builders and users of automobile carriages, another source of the pneumatic's popularity may be recognized. On this point the observations of Mr. J. W. Perry, a tire dealer of Paris, are significant. He says in a letter to the "Horseless Age": "Automobile builders, in the course of competition with each other, have sought to make or build machines of great speed, and each year has brought us a stronger motor, with increased speed, until we see now motors of 35 horse-power that attain speeds of 90 and 100 kilometers an hour (56 to 62 miles). No solid tires could stand such speeds, and only pneumatics of the very best make can stand such strains. I have made tests with 2½ and 3 inch solid rubber tires on automobiles ranging from 16 to 24 horse-power, and on carriages weighing 1 ton to 1½ tons. After many careful tests, I ascertained that both of these automobiles could run safely on a good road at a maximum speed of 42 kilometers, 25 1-10 miles, an hour. When the driver attempted to go beyond this speed (always on a perfect road) the motor was subjected to such fearful vibrations that it threatened its complete demolition. Under the same conditions of horse-power, weights and tires, but on what is considered a bad road, it was impossible to attain more than 15 miles an hour. The same autos, with pneumatic tires made 60 and 70 miles an hour on an average road." While it is perfectly true that the average automobolist never contemplates such high speeds as Mr. Perry mentions, it is only fair to indicate that speed, combined with general road qualities, merely furnishes the test conditions for the jar-absorbing, vibration-neutralizing, and adhesion-increasing properties of pneumatic tires. Furthermore, as the result of numerous experiments, it may be correct to assert that a tire, best fitted to endure test conditions as to speed, is also within certain limits the most suitable type and make to travel under heavy loads, with a minimum of traction effort. For, as most figures seem to indicate, the decrease of traction effort is in ratio with the elasticity of the vehicle's support.

FIG. 97.—An electric ambulance equipped with solid rubber tires.

Economic Efficiency of Pneumatic Tires.— In a paper read before the International Automobile Congress held in 1900, Michelin, the well-known French tire-maker, gave a number of statistics relative to the efficiency of pneumatics, as compared with solid rubber and metal tires. His experiments are interesting as showing how the efficiency of the pneumatic tire, in point of traction economy, increases directly as the speed of the vehicle. Using an electric wagon, weighing 1,980 pounds, on a level Macadam road, and driving through a distance of 1,000 meters in each case under a uniform pressure of 80 volts, he obtained the following figures on traction effort: When running against the wind, with iron tires, 53.9 amperes; with solid rubber tires, 48.5 amperes; with pneumatics, 44.2 amperes, representing a gain of 10 per cent. for the solid rubbers, and of 18 per cent. for the pneumatics, as compared with the iron tires. When running with the wind, other conditions being the same, the figures were: With iron tires, 50.1 amperes; with solid rubber tires, 45.2 amperes; with pneumatics, 41.1 amperes, representing a gain of 9.8 per cent. for solids and of 18 per cent. for pneumatics, as compared with the iron tires. The average speed in both cases was 7.31 miles per hour. At a speed of 12.31 miles, he obtained a percentage of gain 13 and 28, respectively, for solids and pneumatics; the wind, however, being unfavorable during the test of the iron tires. Nevertheless, on a slightly muddy road, he registered respective gains of 10.8 and 20.5, running with the wind at a speed of 12.5; and on a good road bed at a 4 per cent. grade, 1.7 and 7.8, for a 1,210 pound wagon at 6.87 miles. On a 5 per cent. grade covered with "sticky mud," the solid tires showed a loss of 4.7 per cent., and the pneumatics a gain of 19.1 per cent., as compared with iron, at a speed of 11.5 miles; and on the same grade, with half-dried mud, a loss of 7.5 and a gain of 22, respectively, at a speed of 12.5 miles, the vehicle weighing 1,980 pounds in both cases. On the point of such latter variations, Michelin remarks: "The solid rubber tire is better than the iron tire in certain cases, especially at a trot, when the ground is wet, very irregular or covered with snow; but it becomes inferior to iron when the road is hard and smooth; in any case, it never differs much from

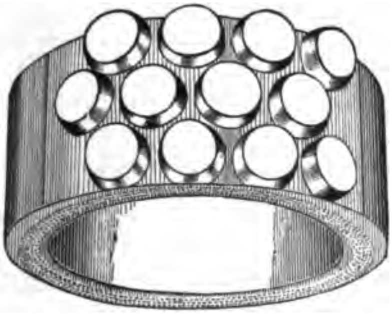


FIG. 98.—The Bailey Single-Tube Pneumatic Tire. The tread is covered with conical projections, which prevent slipping, and at the same time promote traction. According to the claims of the manufacturers, puncture is also made a more remote possibility.

the iron tire, and is always much inferior to the pneumatic. The pneumatic, on the other hand, is superior to the iron tire by one-half." As an average of advantage in traction, the same authority quotes a gain of 18 per cent. in economy of energy, and 5 to 6 per cent. in speed, and by actual tests with weights, suspended on a rope passed through a pulley and attached to a carriage having first, solid, then pneumatic tires, he found a weight of 508.2 pounds required to start with solids, and 437.8 with pneumatics.

Durability of Pneumatic Tires.—In addition to the apparent advantages, in point of absorbing jars, giving better adhesion to the road surface, saving traction effort, and neutralizing the noise and vibration of motors, pneumatic tires, when of sufficient proportions and properly attached to the wheels, are, all advantages considered, also the most durable. That is to say, when calculating the superior speed, comfort and efficiency made possible by pneumatics, we find that their durability is also greater. On this point Michelin says: "Metallic tires are quickly destroyed by the continual hammering to which they are subjected on stone pavements, especially if the wheels carry a heavy load. The metallic tires with which MM. De Dion and Bouton still provide their heavy tractors are very quickly destroyed. In a very short time the tires are flattened and take the form of a trapeze, the large side of which is in contact with the ground." As illustrative of the enormous wear thus entailed, he quotes a noted authority to the effect that the tires of the large transports, formerly used between Paris and Marseilles, lost on an average of 4 grams of metal per kilometer, for every 1,000 kilograms (about one ton) of freight load, giving for the round trip "100 kilograms (220 pounds) of metal left in the ruts of the road." M. Michelin quite properly exclaims: "Colossal figure!" Yet, allowing the utmost exaggeration in faulty calculations or in peculiarly unfavorable road conditions, we can readily credit even this statement on the positive necessity of an elastic support, to "absorb" obstacles, within reasonable limits, rather than offer an unyielding, or unresilient surface for their attrition. Furthermore, we may readily understand that the average of wear, other things being always equal, must be less when the vibrations are absorbed by an air cushion than when left to affect the material of a solid rubber tire. For ordinary traffic, with moderate weights and speeds, the opinions of other authorities, as quoted above, are competent in evidence for the solid, or semi-solid, tire, but practically all concede the superiority of pneumatics for the uses enumerated in the various tests we have mentioned. It is necessary to note in this connection, however, that, despite the enormous ratio of wear for steel tires on heavy motor vans, they seem to be the only possible support for such use. Pneumatics are out of the question, since they cannot be made of combined size and strength sufficient for heavy vans, unless, as has been suggested, several of them be mounted, side by side, in parallel channels in the rim, and the solid rubber tires are only a shade more durable.

FIG. 99.—The New York B. & P. Single-Tube Tire. The extra thick walls of this tire render puncture less easy, and also provide for a "cushion," or semi-solid, support in case of deflation. The method of attachment by lugs and nuts to a semi-circular channel is one adopted by a large number of other tires, affording a secure hold at the base to safeguard against creeping.

Analogies for a Buffing Support.—In a certain and very real sense, the yielding tires of a motor vehicle supplement the action of the springs; although not permitting them to be omitted in construction. In the section on springs we have seen that it is essential to correct theory and practice to consider the vehicle and the road it travels as a working unity—as separate, component parts of one machine. In automobile building the principal concern, in this particular, is the vehicle, which must be constructed so as to endure the most unfavorable conditions of road bed. The effect on the road is quite secondary. In the construction of railroad locomotives, on the other hand, both components of the working unity, the vehicle and the tramway, must be considered: both must be constructed to interact with a minimal wear and damage. In this connection we may quote Matthias N. Forney, a well-known locomotive expert. In speaking of springs, which in locomotives perform some of the functions delegated to flexible tires in automobiles, he says: "A light blow with a hammer on a pane of glass is sufficient to shatter it. If, however, on a pane of glass is laid some elastic substance, such as india-rubber, and we strike on that, the force of the blow or the weight of the hammer must be considerably increased before producing the above named effect. If the locomotive boiler is put in place of the hammer, the springs in place of the india-rubber, and the rails in place of the glass, the comparison will agree with the case above." Similarly, we may mention the use by printers of a wooden block shod with leather, or any suitable substance, which, placed on a form of type and struck sharply with a hammer, is efficient in producing a perfectly level printing surface. The same block, without the yielding face, would undoubtedly batter the type and injure the printing surface. Inversely, it is true that the striking agent may be worn and

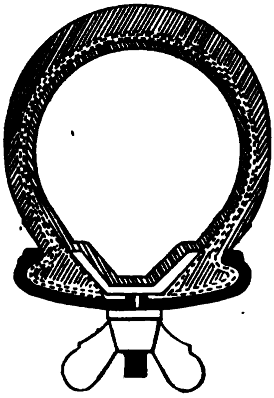


FIG. 100.—The Michelin Clincher Tire. In addition to the lugs and wing nuts which hold the outer tube of this tire to the base, flanges in the length fit into the grooved rim, making the attachment immovable when the tire is inflated.

damaged—"the anvil wears the hammers out, you know," as the poet puts it—hence the need of a buffing medium to protect it also. While in automobiles the effect on the road bed is inconsiderable, the light and delicately-geared machinery must be protected from damage—the anvil must be shod. Whence it follows that, in the absence of anything like the steel rail surface of a railroad, utility of tires increases directly with their yielding and shape restoring properties. The more readily these functions are exercised, the smaller the wear on all the elements composing the working unity of the machine. Furthermore, the necessity in this particular becomes greater in proportion to the weight and contemplated speed capacity of the vehicle, and, beyond the point where pneumatic tires are practical, must be compensated by more efficient springs and lower rates of travel.

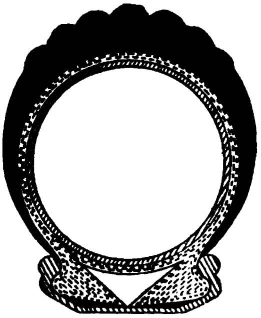


FIG. 101.—The G. & J. Tire. Like the Michelin Tire, this is attached at the base by the fit of the case tube and rim channel, being securely held when the tire is inflated. A flap on the case tube saves the inner tube from pinching at the base.

Structural Points in Pneumatic Tires.—As we have already learned, it is exceedingly desirable that a pneumatic tire should be protected from puncture by thickening the tread, and by some such additional re-enforcement as the insertion of layers of tough fabric. These structural points are embodied in several prominent makes of tire. But even with such devices as these, the tire is not wholly protected from the wear and strain, inevitable in driving under heavy load. Where pneumatics are preferable to solid tires it is because of their superior resiliency, and because of the greater elasticity of the enclosed air. It is evident, however, that these advantages are obtained at the expense of other qualities, since the pneumatic tires, being much more yielding than a solid, even with the greatest compression of the contained air, are immensely more pliable than solids. They are thus liable to be ruptured and rendered useless by an undue tangential pull, or any such conditions as will increase road resistance or promote tearing of the sides or tread. Such conditions must be considered in bicycle construction, but are vastly more important in automobiles.

Fig. 102.—The Dunlop Double-Tube Tire. The attachment is at the base of the inner tube by the endless wires shown, which are pressed against the tubular sides of the rim channel when the tire is inflated, thus affording a positively immovable hold.

The situation as regards the use of pneumatic tires in automobiles could be no better summed than in the words of Mr. Beaumont. He says: "Makers have a problem of considerable importance before them if they are to respond to all the requirements of large pneumatic tires for considerable weights. It is actually on the tread that the obstacle-absorbing or deforming capability is required. Most of the free deformation (under load) must, therefore, take place elsewhere, and this relegates the bending to the thinner sides near the rim and concentrates it there. Only by adopting very high pressures and greater thickness of textile material (at the sides) can this be avoided, and this means hard tires. Except for those users to whom cost is of no importance, this process may go on until the choice between pneumatic and solid or 'compound' tires is a narrow one. It will, however, always be in favor of the pneumatic (the one of light construction, as at present largely used) where the extra cost per mile run is not the first consideration."

Construction of Pneumatic Tires.—The art of designing and making tires has advanced immensely since the first double tube pneumatics were introduced for bicycle use, about twelve years since. The conditions attending their use on all kinds of roads have been carefully observed and the dangers of rupture and puncture have been reduced by proper constructions in a number of particulars. As we have already learned, such tires may be injured in three ways: (1) They may be punctured through the tread by collision with nails, glass, sharp stones, or other cutting obstacles. (2) They may be ruptured at the sides, or on the tread when the walls are made too thin, by violent contact of any sort, by the torsional strain produced by the motor, or when the brake is suddenly applied. (3) They may be cut or worn at points of jointure to the rims, when sufficient precautions are not taken. Other such sources of disablement, besides steady wear might be enumerated, but these categories include most of the familiar occasions of accident. Accordingly, we find that manufacturers have busied themselves in devising and producing means for protecting pneumatic tires at the points most liable to damage. (1) The tread is made of extra thickness of rubber, and further rein-

FIG. 103.—The "Grappler" Tire. Instead of endless wires, this tire carries projecting flanges of metal strips at either side of the base, which press against the inner overlapping sides of the channel rim, affording a secure attachment.

forced by enclosed layers of textile material, which is particularly efficient protection when inserted as strips cut bias. (2) The side walls are similarly thickened and reinforced. (3) The points of contact and jointure are protected with thread or woven fabric.

Causes of Puncture.—According to the experience of several tire experts, the devices ordinarily employed to protect the tread of tires are largely useless from the fact that they very often involve other causes of breakage in themselves, thus enabling the verdict that by far the smaller proportion of tire disablements is due to puncture. By reinforcing the tread beyond a certain definite point we contrive to shorten the tire's life on account of the more difficult bending of the walls, occasioning sharp corners and consequent rupture of the fabric. Like several other causes of disablement, puncture may be said to result most often from the use of insufficient diameter in the tires, rather than from walls too thin or yielding. Indeed, it seems to be a well-ascertained fact that, other things being equal, a tire of proportions suited to the vehicle will resist puncture, while one of

FIG. 104.—The Goodyear Double-Tube Tire. The attachment of this tire is by the strips of wire, woven like a cotton shoestring, which spread apart under the pressure of inflation, thus securing a rigid hold.

smaller diameter will be cut with very much greater ease. The larger sizes of pneumatics, such as the four and five-inch, owe their short-lived usefulness to other causes, yet, Mr. Beaumont, to the contrary notwithstanding, pneumatic tires of four inches diameter are more durable by half than the continuous solid rubber suited to the same size and weight of vehicles, the former representing an average total mileage of 3,000 to the latter's 1,500, as result of a number of tests with heavy high-speed vehicles. In this connection it is well to remark that Mr. Beaumont's statements are accompanied by no figures or reports of tests, which make it probable that they are based on simple calculations gained from experience with vehicles of moderate size in regard to which they may hold good within limitations. The pneumatic tires suited to bear the weight of heavy vehicles are deficient in durability on account of their large proportions —none can be made larger than five-inch diameter—thus no statistics are trustworthy which are based on the behavior of such large pneumatics, as compared with solid tires fitted to smaller vehicles. Solid tires made of size sufficient for the purposes of large racers, unless in some way strengthened lengthwise the tread, as are the indurated fabric tires recently introduced, would quickly tear across and become useless. Heavy vehicles are, therefore, often equipped with sectional solid

Fig. 105.—The Munger Single-Tube Tire. This view shows the tire deflated, so that the longitudinal rubber buffers come together, thus forming a semi-solid, or cushion tire, and preventing the inconvenient consequences generally following this condition.

rubber tires, as they are called, consisting of a continuous rubber band bearing a number of tooth-like sectional pieces, projecting from the circumference. Some manufacturers of such tires claim a good degree of resiliency for them, alleging this style to be "the only tire which has withstood the tremendous wear and tear of heavy automobile use for a satisfactory length of time."

Constructional Requirements in Single Tube Tires.—In an article contributed to the "Horseless Age," Pardon W. Tillinghast, the inventor of the original single-tube pneumatic tire, writes as follows regarding the structural requirements of single-tube tires for automobiles:

"To accomplish the best results and manufacture a tire that will be practically indestructible, a fabric must be employed in which there is no starting point of separation between the fabric and rubber, and one that does not have a substantially smooth surface, or a surface that is continuous in the same plane. The attaching surface of the fabric presented for union with the rubber must be greatly in excess of that furnished by the fabrics in use at the present time. A plurality of plies may be used, some of the plies having a more open weave or construction than other plies, and all plies separated by rubber, which will give in effect a single tube or mass of rubber, having fibrous threads extending throughout the mass to prevent bursting, and binding the whole structure into a substantially indestructible body.

FIG. 106.—The Ball Tire. In this tire the ill effects of puncture are prevented by the solid rubber balls inserted in the tube, which transform the tire into a cushion, positively proof against flattening.

"Another means of accomplishing the same end consists essentially of employing a fabric which, when built into a tire, will have the same effect that a bath towel would if it was inclosed and imbedded in the rubber, with the threads sufficiently strong to withstand the inclosed air pressure, the little loops or fibres extending away from the general plane of the main fabric into the surrounding rubber and being vulcanized therein, furnishing an increased surface for union with the rubber; the general surface line of the fabric in each construction is to be broken so that it is not continuous in the same plane, and there is no starting point of separation between the fabric and rubber."

Two recent patents granted to Tillinghast cover devices for achieving the ends here mentioned. One of these tires is built

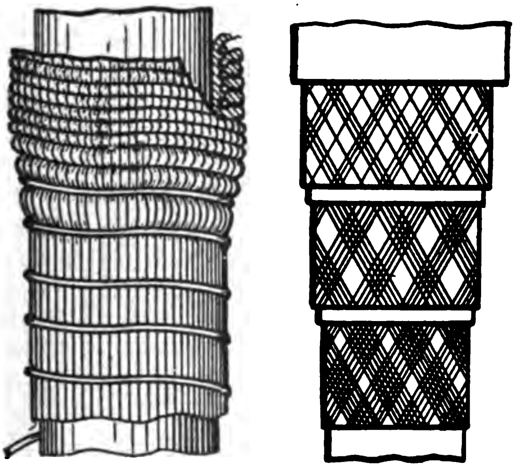


FIG. 107.—The construction of the new types of Tillinghast Single-Tube Tires. The first shows the formation of the fabric into a succession of loops; the second, the open thread fabric tire.

up with a number of strands of thread running longitudinally on the tube and wound spirally with other threads which hold them securely under inflation. The spiral windings are then pushed along the length of the tube, so as to reduce the distance between the windings from one-quarter inch to less than one-eighth inch, with the result that the intermediate sections of the longitudinal threads are pushed up into series of loops, thus forming stronger attachments for the fabric, when held in the material of the rubber wall built up over this layer of threads. Tillinghast's other patent covers a method of strengthening the

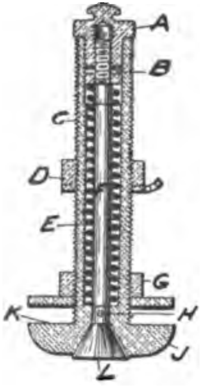


FIG. 108A.

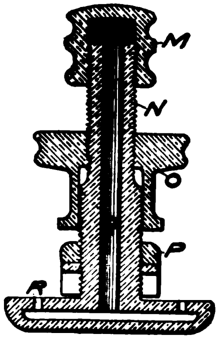


FIG. 108B.

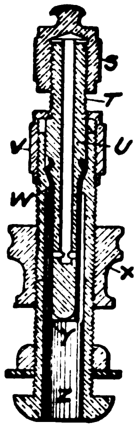


FIG. 108C.

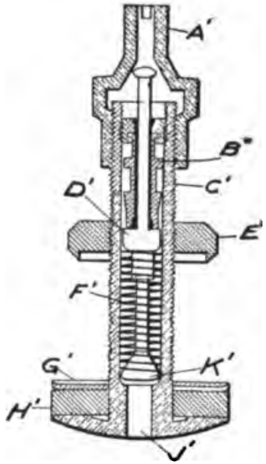


FIG. 108D.

FIG. 108A.—The Sangster Valve. A, removable screw-threaded cover; B, retaining nut, having notches at edge for passage of air; C, the valve tube; D, lock nut and washer for holding stem to the wheel rim; E, helical spring bearing on B and holding valve, L, in its seat; F, valve stem; G, washer holding valve stem to inner surface of rim; H, passages for admitting air into interior of tire; J, head on inner end of valve stem within tire; K, roughened face of J, making joint with the tire walls under air pressure; L, valve seated in J, and carried on the rod, F.

FIG. 108B.—The Welch Valve. This is of the same general description as is used on several double-tube tires. M, the screw cap closing the valve tube; N, the valve tube; O, cap for gripping the wheel rim, on the inner side of which is the nut and washer, P, which presses the wall of the inner tube against the face of the head, R. When the inner tube is fully inflated the holes shown on the upper face of R are closed by pressure of the rubber walls against them.

FIG. 108C.—The Wood Valve. S, the screw cap on the valve tube; T, end of the valve tube; U, tube for air from pump; V, cap holding deflating valve, W, in the seat, loosed when tire is to be deflated; X, nut for holding valve stem to inside of rim; Y, a rubber tube around pipe. U, admitting air to tire when pressure is sufficient through ports at bottom of tube, U; Z, tube admitting air to interior of tire, also head and washer for attaching to inner tire tube.

FIG. 108D.—The Schrader Valve. A′ is the screw cap on the valve tube; B′, the valve seat carried on the binding nut within the tube, C′; D′, the valve; E′, nut and washer for securing tire to the inner face of the wheel rim; F′, spring holding the valve in its seat; G′, H′, washers bearing against outer face of wheel rim; J′, head holding inner surface of tire tube; K′, head at the lower end of the valve stem through grooves at the base of which the air enters the tire.

fabric against any cause that would tend to bursting or tearing the walls, and specifies a series of plies or layers of threads wound on in two diagonal directions, each one being in a more open construction than the last, the closest construction being on the inmost ply of the tire.

Attaching Single-Tube Pneumatic Tires.—The typical method of attaching a pneumatic tire to the wheel is that made familiar in bicycles. Where a wood rim is used the process is, briefly, to thoroughly clean the surfaces of both tire and rim, after which two successive coats of shellac varnish are applied to both and allowed to dry. This varnish is made by dissolving two pounds of gum-shellac in one-half gallon of alcohol. Another method of preparing rubber cements for similar purposes is to dissolve shellac in ammonia. The practice with ordinary shellac varnish is to apply and let dry two successive coats, after which a third coat is given to both tire and rim and the tire is attached, valve first, and secured in position by a good degree of inflation. The varnish is thus able to increase the tire's adhesion to the rim so long as it remains inflated. Thus the inflation of the tire is an essential element to the end of retaining its hold on the rim; for the coating of shellac would speedily tend to lose its grip if the inflation becomes sufficiently imperfect. As the result of insufficient inflation, among other causes, there are two familiar occasions of accident: The tire will "creep," or move longitudinally upon the periphery of the rim; or it will "roll" off the edge sideways.

The Creeping of Tires.—The creeping of a tire is due to the fact that the weight of the vehicle, in process of travel, tends to centralize the pressure on the rubber walls, and cause the tire to bulge just forward of the point of contact with the ground. As may be readily recognized, a continued succession of such bulgings tends both to loosen the adhesion of the tire and the rim, and also to cause the tire to push forward from the ground, and thus around the rim, in the effort to relieve and distribute the pressure. As a result, when inflation is insufficient, great strain and pull will be exerted where the valve is joined to the tire, and a rupture often follows at that point. Even were it possible to obviate the last-named accident, it is evident that the service of a tire, thus loosened by the creeping process is impaired. Moreover, it would inevitably roll sideways from the rim before it had been long in use. Also, if loose, it chafes at the rim and wears quickly.

Attachments That Prevent Creeping.—It seems to be a well-established conclusion that a single-tube pneumatic is more liable to creep than one of the double tube variety. However, this may be in some measure owing to the fact that the structure of double tube tires more readily permits the use of devices for promoting rigidity at the base, and that the majority of them are equipped with such devices. Perhaps the simplest attachment of the kind is that shown in the figure of the New York Belting and

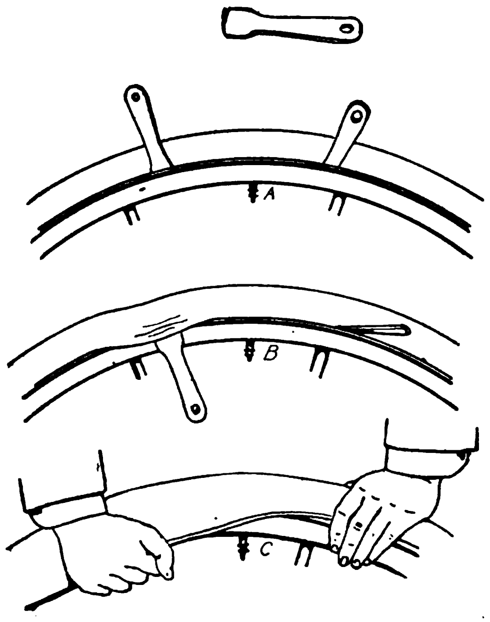


Fig. 109.—Showing the method of removing the case tube of a Dunlop tire. Two tools, like that shown at top of the figure, are inserted between the rim channel wall and the tire, as at A, after deflation. The edge of the tube, being pushed into the central channel, is then raised, as at B. When one wire ring has been raised above the edge of the channel, the case tube is worked off, as shown. (See Fig. 102.)

Packing Co.'s heavy single tube tire. A series of chaplet heads carrying lugs are inserted in the layers of fabric, and these lugs, being passed through holes drilled in the rim, are secured in place by screws and washers. Given strong layers of fabric, as is always essential to the success of this construction, it is evident that the tire will have a very rigid attachment to the rim at the base, by which the evil effects of creeping will be reduced to the lowest point, if the tendency is not practically obviated. It has been widely used with both varieties of pneumatic tires, its success with double tubes having been particularly good in connection with the Michelin clincher and others of similar pattern.

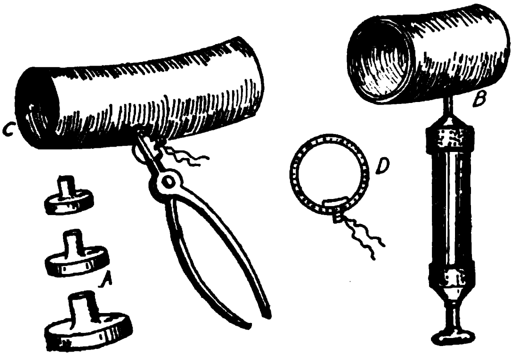


FIG. 110.—Method of repairing a single tube tire. In case of puncture, mushroom patches, as at A, are inserted in the hole, which is usually enlarged with a red hot wire. Liquid cement is then injected, as at B, from a specially prepared syringe, furnished with all repairing outfits. The patch, also cemented, is then inserted, as at C. Its position in the tube is shown at D; where it is pulled into shape by the thread tied to its stem and held by the pressure of inflation. When the tire is inflated hard the patch stem is cut off, and the tube and rim are wrapped about with moist cemented tape, as at D in Fig. 111.

Care and Repair of Pneumatic Tires.—As we have already seen, there are two varieties of pneumatic tire, designated respectively as the "single-tube" and the "double-tube." The latter was invented and introduced by an Englishman, Dunlop, now so widely known for his work in this field, about 1888; the former, by Pardon W. Tillinghast, of Providence, R. I., about two years later. The immense impetus immediately given to the bicycle industry by the successful production of an inflatable support is historic. Previous to this period some bicycles manufactured by the Overmans, of Springfield, Mass., had been equipped with a "cushion tire," which was an arch of heavy rubber attached by its feet. It was an improvement in many respects on the solid rubber tires, until then in universal use, but afforded, at best, a very poor imitation of resilient wheel support. Such a tire, of course, required no inflating, and was not injured by simple punctures in its tread. Hence it involved no troublesome processes of repair, whenever disabled. Pneumatics, on the other hand, are entirely disabled by puncture, although, unless of an unusually serious nature, such injuries may be repaired on the road. In point of ease of repair, the single tube pneumatic is preferable, and this was one of the considerations which led to its almost universal adoption for bicycles, instead of the double tubes first used. The double tubes, however, possess so many advantages in other directions, some of which we have already learned, that the last-named consideration is quite counterbalanced in the calculations of automobile manufacturers. In both varieties of tire the outer layers of rubber, which are alternated with layers of fabric, are of a quality best calculated to resist wear, and, with the enclosed fabric, present a tough, though elastic, surface to the ground. The air tubes in both are of pure rubber, of practically

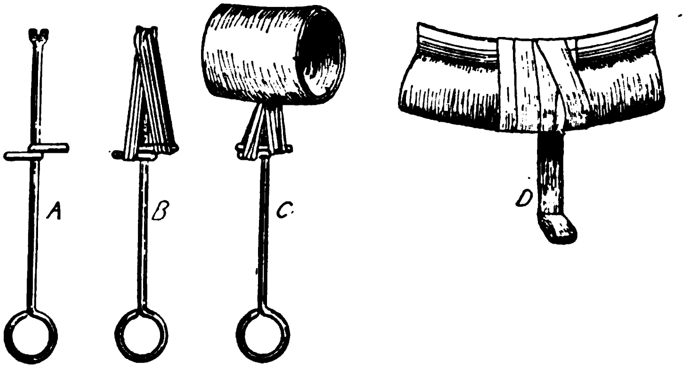
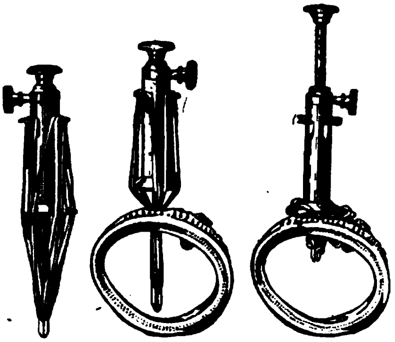


FIG. 111.—Showing method of repairing small punctures. Instead of mushroom patches, ordinary rubber elastic bands are strung on the kind of tool shown at A, as at B. Rubber cement is then injected into the tube of the tire through the puncture, and also smeared on the rubber bands, held as at B. The tool carrying the bands is then inserted in the puncture, as at C; the protruding ends of the rubber bands are pared off, and the tire tube is wrapped with cemented tape, as shown at D.

no strength, but of the greatest efficiency in retaining air. Thus, when the tire is inflated, the air is retained by the inside rubber tube and prevented from leaking through the interstices in the rubber and fabric layers surrounding it. The single-tube tire differs from the double-tube in the fact that the inner, or air, tube is vulcanized to the outer, or cover, tube; while, in the double-tube variety they are separately attached to the wheel rim, and should not be in contact except under inflation. As may be understood on reflection, a puncture through the tread of a single-tube tire may be readily repaired by the use of mushroom-shaped rubber patches, which are carefully inserted in the hole and secured in place with cement under the pressure of inflation. With the double-tube tire, on the other hand, the casing tube must be removed from the inner, upon which suitably-sized patches are then cemented, or still more elaborate repairs made, according to the gravity of the accident. In cases of emergency, as when a puncture occurs on the road, the double-tube tire may be repaired in the same manner as the single-tube, thus involving



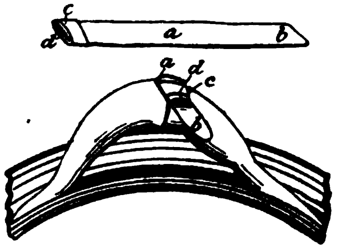


FIG. 112.—The "Kelly" Tire Repairing Tool. This instrument consists of a hollow and slotted awl, made to slide within a cylindrical sleeve having a bell-shaped end. In case of puncture rubber cement may be forced into the tire through the hollow awl. Several rubber bands, generally six, are then attached to the instrument, as shown; one end of each being inserted in the slotted point of the awl, the other ends being hung on the pins projecting at the sides of the sleeve. The needle is then forced in fully, the sleeve being still held away from the surface of the tire. Then the bell-shaped end of the sleeve is set against the tire, enabling the needle to be withdrawn, leaving one end of each band projecting inward through the puncture, the other end being loosened from the pins. The ends of the bands may then be pared off, leaving the surface smooth.

FIG. 112*a*.—The "Sennevoye" Repairing Strap. In addition to the patches for covering punctures on the inner tube, this strap is buckled around, as shown, to further close and protect the injured point.

that the tubes be cemented together, but the repair man can readily cut the adhesion with benzine or gasoline and make the necessary repairs in the proper fashion. With a single tube tire the patch is put on the inside of the air tube, as shown in the figures, being held in place, until the cement sets by the pressure of the contained air. But in case of puncture in an inner tube of a double-tube tire, a patch of cemented rubber or other adhesive is generally attached on the *outside* of the air tube. The adhesion is then maintained, until the cement has set, by the pressure of the air tube against the case tube. In order to afford protection to this patch, rubber bands have been recently introduced which buckle around the injured section and retain the patch under inflation. This operation of patching an inner tube may be performed by the roadside by an experienced hand, when, as frequently happens, necessity so demands.

Proportions of Pneumatic Tires.—Very nearly the most important consideration in point of securing durability and long service in a pneumatic tire is that it should be of dimensions suited to the vehicle it must support. Many accidents and other disablements have arisen from the habit of using tires too small for the load. On the other hand, no particular advantage can come from using tires that are too large. The dimensional limits for practical pneumatic tires are between diameters of 1½ and 5 inches, but the service requirements of most automobile carriages fall far within these figures. As given by a well-known tire-manufacturing firm, the following figures represent about the correct proportions for single-tube tires:

For static load up to 250 pounds, use a tire of 1¾-inch outside diameter.

For static load between 250 and 400 pounds, use tires of 2-inch outside diameter.

For static load between 400 and 600 pounds, use tires of 2½-inch outside diameter.

For static load between 600 and 1,200 pounds, use tires of 3-inch outside diameter.

For static load between 1,200 and 2,500 pounds, use tires of 4-inch outside diameter.

For static load between 2,500 and 5,000 pounds, use tires of 5-inch outside diameter.

For double-tube tires the same figures apply approximately. The manufacturer of the G. & J. tires gives the following figures:

For a static load of 600 pounds or less, use tires of 2½-inch diameter on case tube.

For static load of 600 to 900 pounds, use tires of 2½ or 3 inch case tube diameter.

For static load of 900 to 1,200 pounds, use tires of 3-inch case tube diameter.

Fig. 113.—A De Dion Gasoline Quadricycle, for carrying two persons. This vehicle consists of a motor tricycle whose forward wheel has been removed in order to allow attachment to the two-wheeled fore-carriage, as shown.

Although these figures seem to indicate that double-tube tires of somewhat smaller diameter may be safely used, it is quite certain that the estimates are rather general than specific, and that the question of proper tires for each particular vehicle is settled with reference to the extreme wheel diameter and other proportions. For a motor carriage demands not only an elastic support, but also one of sufficient contact surface to enable its resiliency and adhesion to be efficient under load and at good speeds. Thus, while it is desirable to strengthen the rubber and fabric walls as much as possible against puncture and all undue wear and tear, it is even more important that the cubic content of the air chamber should be of a proportionate size to give commensurately good results.

The Effects of Resiliency in Tires.—A practical test of resiliency may be made by lifting a bicycle or vehicle wheel, bearing an inflated tire, and allowing it to fall a foot or so to the ground. The result will be that the entire structure will rebound a considerable number of times before falling flat, which fact shows how efficient a spring device is interposed between the vehicle and the road surface; also, how great a capacity for absorbing small jars is employed in addition to the springs. If, now, a wheel shod with a solid rubber tire be allowed to fall to the ground in similar fashion, very little, if any, rebound will be observed, which goes to show that the solid tire possesses no capacity whatever for supplementing the springs in the absorption of jars; it throws all of this work upon the springs, which must, in consequence, be exceedingly well calculated, in order to prevent excessive vibration and rocking of the carriage body. This is the reason, as already stated, that it is impossible to attain high speeds on ordinary roads without the use of pneumatic tires. The roads in such cases need to be smoothed in some manner, and, as must be obvious on reflection, this function does not properly belong to the wagon springs and cannot be delegated to them without considerable inconvenience. In a few words, the case of the motor carriage is precisely similar to that of the railroad car, which has the rails of the track to render possible the desired ends of perfect traction and high speed, with the minimum of jar and vibration; it has a ready smoothed road to run on. The motor carriage cannot have such a track, hence must make its own smooth and even traction surface, as it moves along.

Testing Pneumatic Tires.—As seems reasonable on reflection, there is a vast difference in point of resiliency between the various makes and grades of pneumatic tires; also between tires of different sizes, and between single-tube and double-tube tires. Usually the diameter of the tire to be used is calculated with reference to the weight of the vehicle, the idea being that a given diameter of tube will yield a certain proportionate resilient effect and tractive efficiency. There is, however, a very close connection between the two properties, since a tire whose reactive quality is high is superior for traction to one that is more rigid. This is true because greater compressibility entails a broader surface to bear upon the road, while a greater reactive power in a tire in resuming its proper shape after deformation under load, or from contact with obstacles, requires a smaller traction effort to ensure forward progress. Hence, to determine the serviceability of a tire the question of its resiliency as compared with others is very nearly paramount.

Duryea's Tests for Resiliency.—Very few statistics on this subject have been published up to the present time, and very few systematic experiments for determining this point have been made. Perhaps the most exhaustive investigations were those conducted by C. E. Duryea, some years since, by way of determining the merits of various makes of bicycle pneumatics. In a paper on the subject communicated to the writer and subsequently published in a prominent automobile journal, Mr. Duryea writes as follows:

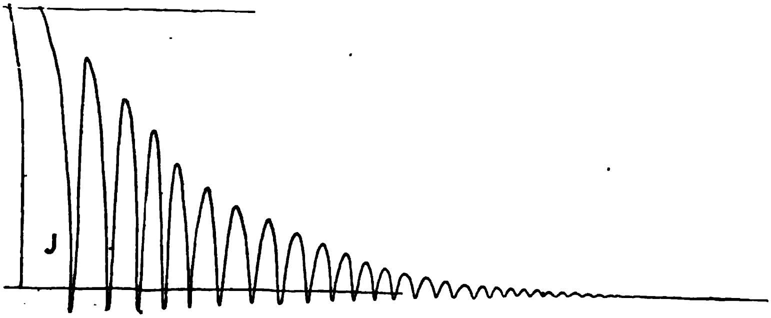


FIG. 114.—Diagram showing test of resiliency of a pneumatic tire, on wheel, dropped to the floor from a measured distance above, and tracing its rebounds by a resiliometer, as described.

"In the course of experiments with cycle tires, the writer built a simple resiliometer, believed to be the first in the United States, for the purpose of testing the comparative resilience of the different tires then in use. This device consisted of a bar six or eight feet long, forming an extension of a wheel axle, the end of the bar being pivoted to the wall at the height of the axle. On this bar a pencil was fixed to bear against a vertical plane surface adapted to slide toward or from the wheel. On this surface paper cards were attached, and the tire to be tested was placed on the wheel. The wheel was then lifted a given distance and supported by a prop. Moving the slide produced on the card a line indicating the height from which the wheel would fall. Tripping the prop and moving the slide at the same time produced a series of zigzag lines, as shown in the cut, each being lower than the preceding in a practically fixed relation. After the wheel quit bouncing, another line would be drawn showing the normal position of the wheel when resting on the ground. The height of the first rebound above the lower line, as compared with the distance between the lines, was taken as the measure of the tire's resilience for the purpose of comparison with other tires.

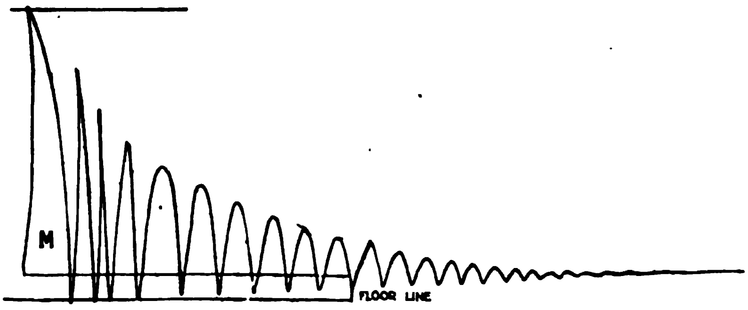


FIG. 115.—Diagram illustrating resiliometer record of a pneumatic tire, on wheel, dropped from a given distance to a one-inch round rod, and recorded as the resiliometer slide is moved.

"Many hundreds of cards were made, both from smooth surfaces and from obstacles, such as a one-inch rod resting on the floor across the path of the tire. A tire that gave good results from a smooth surface would not necessarily give good results from an obstacle, while the tire that gave good results from a rough surface generally gave good results from a smooth. Tires of equal size and weight, as nearly as possible, were tested at equal air pressures and also at different air pressures. The results of the tests showed that good tires possessed a resiliency of eighty-five to ninety per cent. under favorable circumstances, while other tires fell as low as fifty-five to sixty per cent. under the most favorable tests that could be given them—clearly a vast difference, and to the writer an unexpected one.

Tests on the Quality of the Fabric.—"The tests further showed that the fabric of the tire should be free to yield in a direction lengthwise of the tire and that the air should be confined by threads encircling the tire transversely, i. e., around its smallest section. These tests were amply borne out in practice by the adoption of thread tires, which are admitted to be much faster than woven fabric or canvas tires.

"The tests further demonstrated that the tire should be held on by some means other than the strength of the fabric, for if the fabric must hold the tire the threads must run more or less lengthwise of the tire, whereas, as already stated, the best results were obtained by placing the threads crosswise of the tire. This same placing of the threads has an advantage in the matter of durability, for it is quite evident that the strength of the fabric will be preserved longer if it is called upon to hold the air only than if doing double duty by holding the tire on the rim as well.

"A third factor, which has an important bearing on light tires, or with heavy loads, is the receptive ability of the tires. If the fabric is free to yield lengthwise the obstacle will push into the tire without damaging the fabric and without lifting the load. With an iron tire, for example, an obstacle like a marble will force the load to be lifted over it, whereas a rubber or pneumatic tire with fabric free to yield lengthwise simply receives the marble without lifting the load. Prints of the positions assumed by the surfaces of different tires were made by placing a lead wire on the obstacle and running the tire over it under load. This outline showed very conclusively that one tire would take its support from the ground, simply swallowing the obstacle, while the other attempted to lift the load just as a solid hard tire would do, in which case the strain on the fabric concentrated at the point of the obstacle must be very great."

Tests on the Shapes of Rims and Tires.—In addition to the results attained, as above, Mr. Duryea also made cards illustrating the relative merits of single and double tube tires and of rims of various shapes and depths. His conclusions were that:

"The ordinary round tire lying in an arc-shaped rim, as is the common method, cannot utilize its side walls properly when meeting an obstacle, since it is flattened toward the rim and caused to bend at the side abruptly at two places; being bent outward over the edge of the rim and inward at its widest point. The outward bend, together with dirt which may get between tire and rim, tends to chafe the tire on the edge of the rim, a phenomenon commonly known as rim cutting. The other bend cannot stretch the outer layers of fabric, so it must compress the inner fabric and inner rubber, which compression rapidly causes a crack, weakening the tire from the inside, with the result that in a short while the tire begins to swell along the sides and finally bursts. Any rim, therefore, which will hold the tire at the bottom only, and yet preserve it from rolling sidewise on the rim, is conducive to long life of tire, for it leaves the side walls free from short bends and increases the depth of the tire, which increases its beneficial results as well."

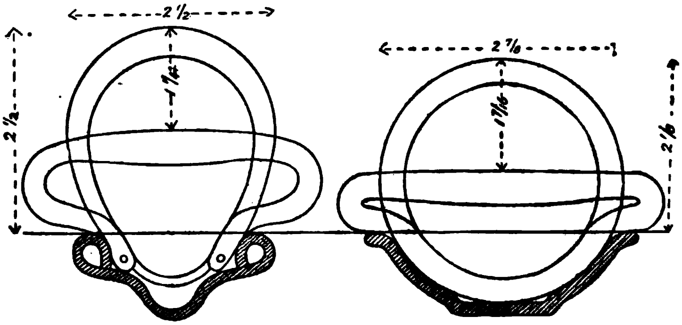


FIG. 116.—Diagram illustrating the relative degree of flattening consequent on deflating a double-tube pneumatic, mechanically secured to base, and a cemented single-tube pneumatic, through one-half diameter above edges of rim. Note the sharp corners of the single tube.

Relative Efficiencies of Tires.—In order to illustrate his contention, Mr. Duryea prepared figures of a mechanically fastened double-tube tire and of a single-tube cemented tire with arc-shaped rim, showing their shapes when inflated and when deflated to one-half their diameter. His conclusions were that, since a double-tube tire may be compressed further than a single-tube, a small tire of the former variety is as efficient in smoothing the road as a larger one of the latter variety, while, at the same time, a proportionate deflation of the two shows a further advantage, in that the walls of a double-tube tire are bent much shorter for a given compression than in the single tube, and are forced against the edges of the rim with much less compression, and that, further, the single-tube tire does not flatten out so widely in proportion to its diameter as does the double tube, which latter fact is of importance, because added width means added supporting surface, tending to resist further compression as it increases. He, therefore, concludes that:

"The best automobile tire is the one mechanically fastened so as to relieve the fabric from the strain of holding the tire in position. Its fabric must be as strong as possible, because of the heavy service which means a long fibre closely woven canvas of the greatest possible strength and the fewest necessary thicknesses, which arrangement is less liable to puncture or tear than any thread fabric and is yet as flexible as the necessary strength will permit. Being mechanically fastened, the fabric need not be stretched in the direction of the length of the tire which increases the resilience and lessens the strain and liability of rupture in passing over obstructions."

As may be readily understood, a further advantage gained by using a double-tube tire, mechanically fastened at the base, is that the sidewise strains encountered in turning corners, are not so liable to cause rolling off the rim. In bicycles this danger is largely averted by the rake, or inclination, taken by the wheels in turning corners, which maintains the entire wheel-structure, including the tire, in one plane. But, in automobiles this rake cannot be obtained except with the front or steer wheels, the result being that the strain brought upon a tire in turning corners at high speed is enormous. A tire, standing high above the rim, and rigidly attached at the base, is capable of a very considerable sidewise deformation without particularly great danger of rupture or other accident. Howbeit, if the inflation be insufficient, such side strains are very liable to loosen the fastenings, particularly when clamps are used.

Attachments for Double-Tube Tires.—The G. & J. tire has several points of resemblance to the Michelin clincher. The outer, or casing, tube carries longitudinal flanges, intended, as is shown, to fit into the grooves on the rim. The method of attachment is, briefly, to insert the flange on the side carrying the rubber and fabric flap piece, shown beneath the inner tube; then to set the inner tube in place, valve first; finally, to insert the flange on the side of the outer tube still unattached beneath the opposite groove on the rim, and beneath the flap piece already mentioned. The side last attached is first disengaged in the act of removing the tire from the rim. By inserting the flanges of the outer tube in the grooves of the rim a very firm grip is obtained, which cannot be disturbed without the use of a special tool furnished with each set of these tires. Moreover, this secure attachment at the base of the tube neutralizes the tendency to creep, which effect is greatly increased by perfect inflation. The secure attachment, obtained by the flanges, is augmented in the Michelin tires by the use of such lugs and screws as are shown in connection with the type of tire described above. The danger of puncture is largely overcome in this tire by thickening and corrugating the tread, but should puncture ever occur, it is possible to readily detach the outer tube from the wheel rim, in order to apply the necessary cement and patches to the inner.

FIG. 117.—"Automotor" Gasoline Phaeton, with rumble seat, illustrating a recent design in light motor carriage construction.

The Dunlop Double-Tube Tire. — With the Dunlop double-tube carriage tire the process of attaching is somewhat similar, although the flanges are here replaced by one or several endless wire rings, inserted in the fabric of the outer tube, and of such length as to fit the rim tightly at the base of the tubular retaining flanges or edges, as shown, when the inner tube is inflated. The process of attachment of the outer tube is, briefly, to insert the wire edge of one side of the outer tube in the bottom of the deep central channel of the rim, which, as may be readily understood, permits the ring to be forced over the tubular edges with very slight effort. The inner tube is then put into place, valve first, after which the other wire ring is inserted in the bottom of the central channel and similarly urged over the edges of the rim. By inflating the inner tube, the wire rings are forced against the bases of the tubular edges; all tendency to roll or pull off under this outward stress being thus overcome. A very firm and rigid attachment is also made at the base, completely around the rim, with the result that creeping is rendered impossible. The tubular retaining edges obviate rim-cutting, as the tire is forced against them, under the weight of the carriage. The layer of fabric at the base of the inner tube eliminates all tendency to pinching or wearing of the rubber against the corners of the case tube, which was a constant source of anxiety in some of the earlier patterns of this tire made without such protection. Some Dunlop tires, intended for heavier service, have an additional, detachable tread-piece, which may be readily replaced by proper appliances when worn, thus ensuring a much longer life to the tire and acting as an additional precaution against puncture.

The Goodyear Tire.—The theory of producing firm attachment between tire and rim by the use of endless wire rings, or bands, is also applied in the Goodyear vehicle tire, as is shown in an accompanying figure. The walls and tread of this tire are composed of the usual layers of fabric and rubber, which are continued also into the square portion intended to fit the rim. At either side of the base, and so disposed as to bear against the outwardly flanged edges of the rim channel, are ribbons of wire inserted in the fabric of the tire wall. The wires of these ribbons are braided together, like the threads of a cotton shoe string or a binding tape, so as to shorten in length under any impulse to spread the strands apart. The braiding, being thus spread by the inflation of the tire, contracts in length so as to grip the rim very firmly, and prevents all creeping or other movement tending to cut either the wire or the fabric. The arrangement permits the use of a shallower rim than is possible with most other pneumatic tires.

A Non-Collapsible Tire.—The Munger single tube tire, as shown in Fig. 105, bears on its upper and lower walls longitudinal rubber buffers, so shaped as to fit together in case the tire becomes deflated from any cause. In this contingency it is not necessary that the wheel should run on its rim, to its obvious destruction, since these buffers prevent complete collapse and to a large extent give the effect of a solid tire. The tread buffer also renders puncture from sharp obstacles an exceedingly remote possibility. It further presents a greater surface than does the ordinary round-faced tire for the displacement of air, and, as a result, can be used with less inflation with consequently better resiliency and power to absorb vibration. One disadvantage, however, lies in the lips overhanging the edges of the rims, which would seem to prevent the sides from bending as freely as desirable.

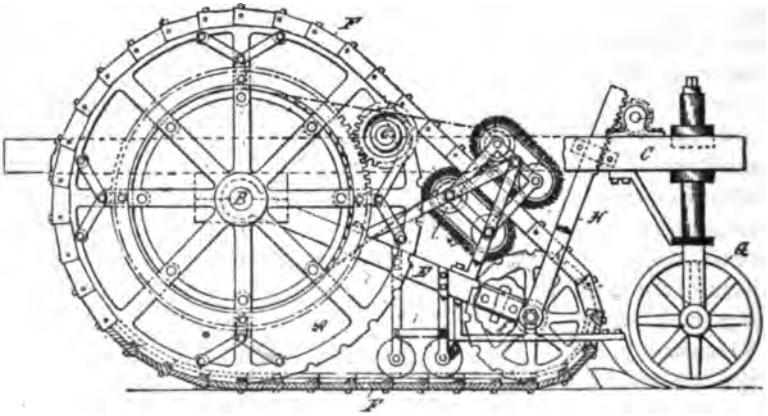


FIG. 118.—Wheels and running gear of a "track-laying" tractor, designed to travel on ordinary roads with a small amount of surface friction without the use of pneumatic tires.

Tractive Devices: Track-Laying Wheels—In order to attain the end of superior traction, otherwise than by the use of pneumatic tires, several inventors have devised and patented road locomotives that lay a track as they advance. This is accomplished by the use of a suitably constructed chain belt passing around the wheels of the vehicle and driving them from a sprocket directly geared, or on a countershaft. One of the best designed of these is shown in an accompanying figure. It would undoubtedly serve the ends of ready traction and power economy, but has never been tested under high speed conditions. Generally speaking, it seems hardly suitable for motor carriage purposes, and is mentioned only to show that the necessity met by pneumatic tires has been repeatedly apprehended by vehicle designers.

A Double Interacting Elastic Wheel.—Another device of more recent invention and even greater excellence of design deserves mention in this connection. It is, in short, a wheel contrived to combine the durability and good tractive properties of a solid tire with the resiliency of a pneumatic, while quite effectually protecting the latter from puncture and other wearing strains of travel. These ends are achieved with a very ingenious mechanism, by which two wheels are hung on one hub or axle boss, as shown in the accompanying diagram, the outer one being shod with an ordinary solid tire, the inner with a pneumatic. Of course, in order that the desired effect should be perfectly achieved, it is necessary that there should be some play between the two wheels, permitting the weight of the vehicle to bear against the lowest point of the pneumatic tire on the inner wheel, without involving distortion of any part of the structure. Accordingly, the hub is constructed in sections, between which considerable movement is possible. These sections, as constructed for several types of these wheels, are shown in accompanying sketches, and are, briefly: A central hub plate—or spoke hanger where wire spokes are used—which is perforated to fit loosely over the axle boss, and has also a slot cut on two opposite radii from the nave; two other hub plates, or "half hubs," similarly perforated and interiorly slotted, and also arranged for attaching spokes; two "intermediate floating guide plates," with keys set upon reverse sides at right angles to each other, which guide plates, being set between each of the outer hub plates and the central hub, have their keys or splines inserted in the grooves above mentioned, thus permitting a complete rotative movement between the central hub and the outer hub plates, which gives the desired play between the former and the two latter.

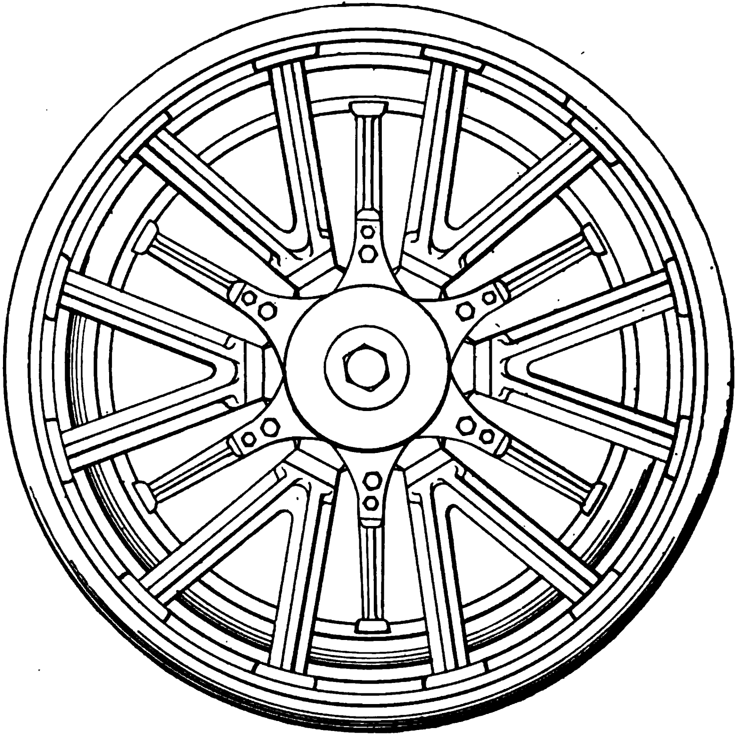


Fig. 119.—The Double Interacting Wheel, constructed for heavy carriage use. As may be seen, it consists of two distinct wheels hung on one axle and in the same plane. The larger has a solid rubber tire for the sake of good traction, the smaller has a pneumatic for the needed resilient effect.

Construction of the Double Interacting Wheel.—The central hub supports the spokes of the outer, or larger, wheel, which is shod with the solid rubber tire, and the outer hub plates attach similarly from either side to the inner, or smaller, wheel, which is shod with the pneumatic. Since the hub of this inner, or smaller, wheel fits snugly over the axle boss, the outer one having considerable play around it, it follows that the effect of the load is to bring the weight upon the pneumatic tire, which bears against a circular channel, thus delivering the benefit of its resiliency to nearly one-half the wheel diameter, rather than to only one point at the ground. Thus, while a free movement radially is permitted by the interaction of the wheels, they are so locked, by the keys or splines on the floating guide plates of the hub, that they are compelled to rotate together. A wheel thus constructed may be tested in the manner above specified, and will show the effect of the pneumatic tire's resiliency, as much, if not more, than if the tire were mounted on the outer rim in contact with the ground. At the same time the tire is perfectly protected from puncture; is not liable to creep, since the strain of the load, delivered at the point of contact on the outer rim, is transmitted through a V-shaped area to the interior of the wheel, thus involving that the pneumatic tire be bound by a considerable arc of its outside containing channel. Such a construction and operation also prevent destruction of the pneumatic from other causes, such as wrenching and kneading on the rim, that result in tearing and overheating. This means that a cheaper pneumatic tube may be used than would be possible against the ground under heavy load.

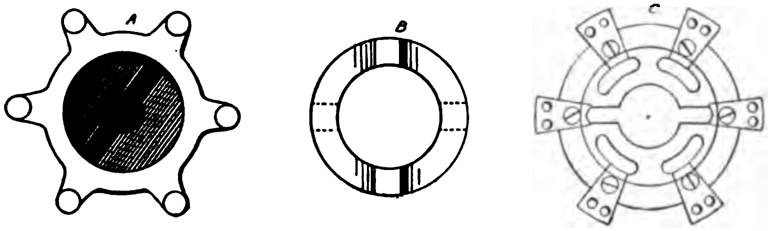


FIG. 120.—Elements of the Compound Hub of the Double Interacting Wheel. A is the outer hub plate, showing interior slot. B is one of the two floating guide plates, carrying keys or splines, arranged on either side, as indicated. C is the central hub plate, also slotted, and arranged for hanging spokes.

CHAPTER ELEVEN.

ON THE CONSTRUCTION AND OPERATION OF BRAKES ON MOTOR CARRIAGES.

General Requirements in Brakes.—An important subject in connection with the construction and operation of motor vehicles relates to the brakes used for retarding the movement of the carriage when it is desirable to either come to a more or less sudden stop, or to hold the carriage stationary on the side of an incline. Several conditions are essential to the designing of brakes for motor carriages, among which we may mention ease and rapidity of operation and the maximum of braking effect, with the minimum of power exerted at the operating lever.

Varieties of Construction in Brakes.—There are two kinds of brakes in familiar use on vehicles of all descriptions: Shoe brakes, which operate by the pressure of the contact surface or shoe upon the periphery of the wheel tire, and drum brakes, which operate by tightening a band around a drum, either on the hub of the wheel or on the case of the differential gear. Both varieties are used to a considerable extent on motor vehicles, although most authorities agree that shoe brakes are unsuitable for use on wheels tired with pneumatic tubes. The reason given for this opinion is that the constricting effort due to pressing the shoe against the tire is, like the ordinary shocks experienced in travel, largely absorbed by the tire itself, with the result that it is liable to be rent or torn from its attachment to the rim. On the other hand, it has been asserted by at least one well-known manufacturer of motor vehicles that shoe brakes may be safely and satisfactorily used on pneumatic-tired wheels, provided the surface contact of the shoes extend over a sufficiently extensive arc to prevent the strain from being concentrated on small areas of the circumference. This authority asserts that he himself has used a motor tricycle for several years, the wheels of which are equipped with a shoe brake constructed according to his idea. The result is, he states, that the contact surface of the shoe has been worn much more rapidly than the tire surface, which seems to suffer very little, if any, more than would be the case with the use of any other form of brake. Whether his experience in this regard would be borne out in general practice, it is not necessary to inquire, the fact being that nearly all motor vehicles at the present time operate with drum and strap brakes.

Principles of Band Brake Operation.—Among the advantages possibly to be alleged for the drum and band brake we may enumerate the facts that, with ordinary connections, they are much more readily operated and with much greater effect while on any showing involving a minimum of wear on the moving parts. As may be readily understood, the operation of the drum and band brake is a reversed application of the principle of torque, as already explained in connection with the electrical motor. As there explained, if the power acting upon a rotating shaft be equal to the weight of fifty pounds constantly applied, and the pulley attached to the shaft be twice the diameter of the shaft, the available power at the periphery of the pulley will be just one-half that exerted on the periphery of the shaft itself. This statement is equivalent to saying that if a rope carrying a weight of fifty pounds be wound about a pulley, whose diameter is one foot, mounted on a shaft, whose diameter is six inches, it will exactly balance a weight of one hundred pounds on a rope wound about the shaft. The constantly applied power of slightly over twenty-five pounds at the periphery of the pulley will be sufficient to rotate the shaft against a resistance of fifty pounds on the shaft. It thus appears that the braking power, applied around the periphery of the brake drum, is efficient in retarding the momentum of a forward-moving vehicle in very nearly the inverted ratio existing between the diameters of the drum, or pulley, and the rotating shaft to which it is attached. In the practical application of this principle, however, it is obvious that there must be very definite limits to the diameter of the brake drum, or pulley, beyond which it would be undesirable to go. According to the practice adopted by light motor vehicle manufacturers, the average diameters of brake drums range between eight inches and two feet, the principal item of variation in this respect being the weight of the vehicle itself.

Beaumont's Formulæ for Brakes.—It is possible to obtain a very efficient band brake on a very moderate diameter of drum, owing to the fact, which need scarcely be mentioned, that the braking effort is never applied until the motive power is disconnected from the running gear. In a steam vehicle, the first act is to shut off the steam from the cylinder; in a gasoline vehicle, to throw off the main clutch; in an electrical vehicle, to open the circuit of the motor and batteries. The resistance against which the brake must then operate is found to be purely a consideration of the vehicle's weight, its velocity and the acceleration due to gravity. This principle is already stated by Mr. Beaumont, as follows:

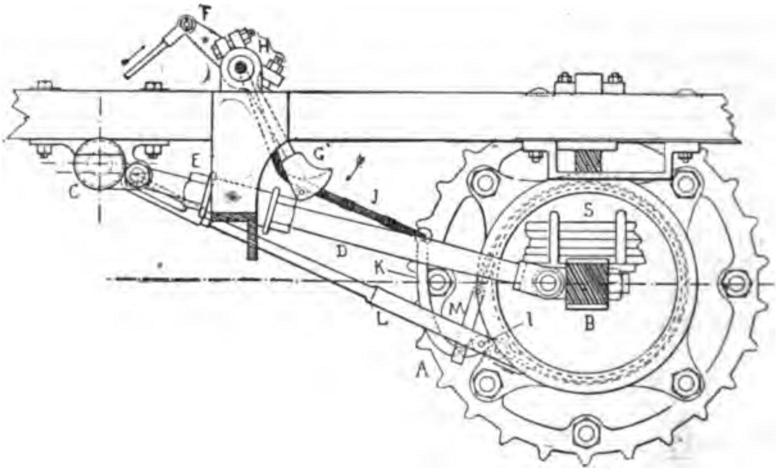


FIG. 121.—The Hub Brake and Operating Levers Used on the Panhard Carriages.—The arm, F, being pushed in the direction of the arrow, causes the arm, G, on the same pivot, H, to move in the opposite direction, as indicated by the lower arrow. Through this arm, G, runs the cable, J, as shown, which, pulling on the arm, K, pivoted at *l*, pulls the strap, shown by dotted lines around the drum, S. The other end of the strap attached to the short arm of the lever, K, is thus drawn toward the same point; a tight frictional bind being the result.

"When it is necessary to determine the brake power to stop a vehicle of a given weight running at a given speed, in a given distance, and, by this means, arrive at something like due comprehension of the necessary parts brought into play to effect this stop, it must first be pointed out to those who overlook the fact, that the strain put upon a brake to effect a stop in a given distance increases as the square of the increase of speed; so that to stop a car running twenty miles per hour requires four times the power necessary to stop it in the same distance when running ten miles per hour. Commonly, all calculations relating to the acceleration of masses at high speed are calculated on the basis of distance covered in feet per second, and hence the work or energy lodged in a mass having a given weight and moving at a given velocity in feet per second is given by the following expression:

$$K = \frac{W\ v^2}{2\ g}$$

in which *K* represents the work, or energy, lodged in the moving mass; *W* represents its weight; *v*, its velocity, expressed in feet per second, and *g*, the acceleration due to gravity, or 32.2 feet per second."

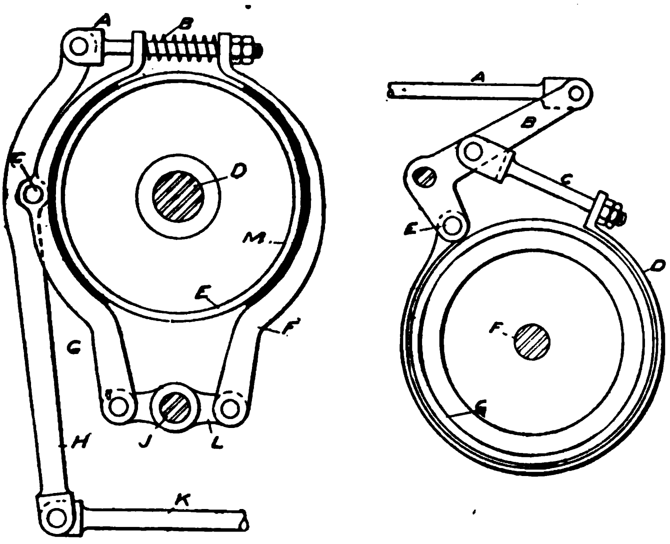


FIG. 122. FIG. 123.

FIGS. 122 and 123.—Two Forms of Constricting Band Brake. In the first figure, the drum, E, rotates on the spindle, D. Two shoes, F and G, joined to the link, L, pivoted at J, are pressed against the periphery of the drum, E, when the link, K, moves the lever, H, pivoted at C, so as to pull the arm, A, on F, by compressing the spring, B, normally holding them apart.

In the second figure, the band, D, surrounding the drum, G, is drawn tight, when the link, A, operates the bell crank, B, thus producing a pull through its attachments at C and E.

From the above formula, Mr. Beaumont proceeds to derive other essential elements, such as the efficient power necessarily applied to stop a vehicle of given weight, in a given length of travel.

Reducing the expression for feet per second to miles per hour, according to the usual standard, and, assuming the weight of the vehicle to be one ton (of 2,240 pounds), he reduces the formula, as follows: One mile being 5,280 feet, and one hour, 3,600 seconds,

$$1 \text{ mile per hour} = \frac{5{,}280}{3{,}600} = 1.466 \text{ feet per second.}$$

Whence $\frac{W\ v^2}{2\ g} = \frac{W \times (1.466)^2}{64.4} = \frac{W \times 2.15}{64.4} = W \times 0.0334.$

Then a vehicle weighing one ton, traveling at ten and twenty miles per hour, by the formula,

$$K = W\ V^2 \times 0.0334,$$

in which V represents miles per hour, will be for 10 miles $2{,}240 \times 100 \times 0.0334 = 7{,}480$ foot pounds; for 20 miles $2{,}240 \times 400 \times 0.0334 = 29{,}920$ foot pounds.

To Find Distance in Which Brakes Will Act on Vehicle's Speed.—Then, taking k as the coefficient of friction between the tires and road surface, which is approximately 0.60 for rubber tires; and taking W as the proportion of the total weight carried by the wheels to which the brake is applied, which may be assumed to be 0.6 of the whole, the maximum distance required to stop the vehicle on the level, on an ordinary road, whose surface resistance is, supposedly, included in the expression, k, may be expressed by l, as follows:

$$l = \frac{W\ V^2 \times 0.0334}{k\ w}$$

Then, for a vehicle weighing one ton, tired with average rubber tires, traveling at a momentum of 10 and 20 miles per hour, respectively, we have:

$$l = \frac{7{,}480}{0.6 \times 1{,}344} = 9.3 \text{ feet at 10 miles, and}$$

$$l = \frac{29{,}920}{0.6 \times 1{,}344} = 37.1 \text{ feet at 20 miles ;}$$

these distances representing the maximum, with a braking effect sufficient to cause the wheels to skid.

To Find the Required Braking Pull.—In order to find the necessary pull, p, on the brake band, the following formula is given:

$$p = k\,w = \frac{W\,V^2 \times .0334}{l},$$

which for one typical vehicle, moving at 20 miles per hour, gives,

$$p = \frac{29,920}{37.1} = 806 \text{ pounds.}$$

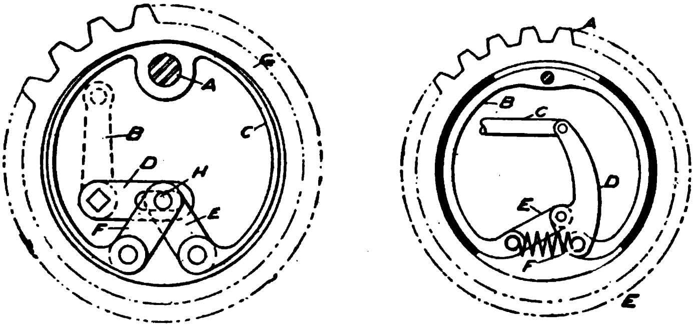


Fig. 124. Fig. 125.

Figs. 124 and 125.—Two Forms of Expanding Band Brake. In the first figure, the gear, G, has an internal bearing surface, within which is the band, C, pivoted at A, a point separate from G. The arm, B, of the bell crank, B D, being moved to the left, spreads apart the two links, E and F, connected to D at H, thus pressing both ends of the band, C, against the internal bearing surface of G, and producing the necessary braking friction.

In the second figure, the gear, A, similarly arranged with an internal bearing surface, contains the expanding band, B. When the link, C, is pulled, the lever arm, D, double-pivoted at E and F, causes the two ends of the band, B, to press against the internal bearing surface of A, thus creating friction. The spring shown normally holds the two ends of the band apart.

Varieties of Drum and Band Brake.—As shown by accompanying illustrations, there are two general types of drum brake, the first consisting of a drum or pulley, around the circumference of which is a metal strap faced with leather, which is drawn tight whenever it is desired to furnish the resistance necessary to check the rotation of the shaft; and expanding band brakes, in which a similar metal strap, faced with leather or other suitable substance acts against the internal surface of a rotating drum or pulley. The former type is, however, at the present time the most usual construction, although the latter is seeing an increasing popularity.

In some forms of constricting band brakes, instead of a metal strap extending entirely around the drum, two shoes pivoted at a certain point, and having their inside faces faced with leather, are tightened against the drum by a suitable lever. In practically all forms of expanding band brake the band is attached to the outside frame, at one point of its circumference, and is suitably tightened by a toggle joint operated by a lever. This is the plan adopted in the several types shown in the accompanying illustrations.

FIG. 126.—The "Duryea" Expanding Break. The two ends of the metal band are separated by the lever, A, and the adjusting screw, B, which is swiveled to the hinge, C. A forward pull on lever, A, through the chain pull, indicated by D, causes the two ends of the band to be thrust apart and bear against the inner surface of the sprocket. The extension spring, E, normally holds the band away from this friction surface. The two lugs, F F, attached to a spider hung on the axis of the sprocket, take the braking effort from the bottom of the band more into the line of travel. A framework, indicated at H and I, supports a leather guard covering both the chain and sprocket.

The Care of Brakes.—In successfully operating a motor carriage it is particularly essential that the brakes should be maintained in good working order. This involves that the levers and connections should at all times operate perfectly, and that no worn or loose bearings should be neglected. Furthermore, and most important, the friction surface between the band and the drum should be constantly and carefully guarded from oil deposits, which will certainly render the braking effort useless. If oil collects between the band and the drum surface it may be cut out with gasoline, and the parts then carefully wiped with a suitable rag.

CHAPTER TWELVE.

ON BALL AND ROLLER BEARINGS FOR MOTOR CARRIAGE USE.

The General Uses of Rotative Bearings.—The practical problems involved in the construction of bicycles and motor carriages have given a great popularity to ball and roller bearings for use in connection with almost every variety of rotating shaft. As we have already seen in several constructions mentioned in previous parts of this volume, ball bearings are used in a large variety of different devices, in order to allow of the greatest possible ease in turning with the smallest friction and wear. The most important use, however, for ball and roller bearings, in both bicycles and motor carriages, is on the axles of the road wheels. For this purpose, although ball bearings are eminently satisfactory on the wheel axles and pedals of bicycles, they are for a number of reasons unsuitable for the heavier weights and higher speeds of motor carriages. Accordingly roller bearings have taken their place almost exclusively in this connection.

Rotating Supports vs. Sliding Surfaces.—The principal object involved in using ball and roller bearings on bicycles and motor carriages is to secure economy of traction effort, with ease and rapidity of driving, as well as a minimum of starting effort at the beginning of travel. A few simple principles will serve to fully explain the reasons for this fact. When we have a plain wheel bearing, such as is used on ordinary horse carriages, consisting of a simple tapered boss, with a similarly shaped hollow axle-box rotating around it, there is a considerable effort necessary at starting from rest, a good proportion of the power being consumed in resisting the friction between the sliding surfaces. This resistance is very largely due to adhesion between the two sliding surfaces, due to cohesion of the lubricating oil or grease. As a matter of fact, it may be easily understood that the sliding action of two round surfaces, one within another, may be readily compared to the sliding of one plane surface upon another. The first difference in point of resistance and effort necessary to overcome inertia, as between two such surfaces, when sliding against one another directly, and when some kind of rollers or rotating supports are interposed, is a matter of the commonest experience. The heaviest objects may be readily moved or slid along the ground when rollers are placed beneath them; also the heaviest loads when carried on wheels of suitable breadth and diameter may be handled with a degree of ease, increasing directly as the ideal conditions are approximated. This principle is the very one that is applied in the practice of substituting ball and roller bearings for ordinary plain bearings. Instead of two plane surfaces having rollers interposed, the two surfaces are given a rounded contour, the one being within the other, and the same rule of increased ease of relative movement applies.

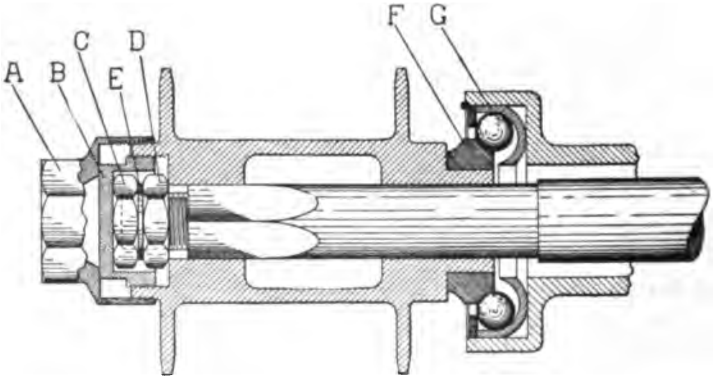


FIG. 127.—One Form of Driving Axle Using Ball Bearings. The hub is secured in place by the nuts and binders shown at A, B, C, D, E. At its inner extremity it carries a cone, F, which works on the ball race, G. The hub is thus suspended on the ball race, which also acts to neutralize end thrusts.

Rotative Bearings vs. Plain Bearings.—The obvious reason for the superior traction qualities obtained by the use of both kinds of rotative bearings is that the friction and resistance between the relatively moving surfaces is so greatly distributed that it is reduced to a practically negligible quantity.

One of the most familiar evidences of loss in power through the friction of the sliding surfaces, in plain bearing wheels, is seen in the fact that the hubs speedily become loose, greatly to the detriment of balanced rotation of the wheels and waste of traction effort. With properly adjusted ball or roller bearings this result is indefinitely delayed, even where it is not entirely obviated, and the wheels on which they are used not only give the best results in point of tractive efficiency, but also in the duration of their period of usefulness.

The Limitations of Ball Bearings.—Of the two varieties of rotative bearing, however, we may state on the authority of several writers on the subject that ball bearings have very decided limitations in point of useful operation as compared with cylindrical roller bearing surfaces. Balls have been successfully used on bicycles and numerous other constructions, but even at their best involve a considerable loss of power, owing to the fact that they roll in opposite directions and constantly rub against one another, with the result that the friction speedily wears them out, involving constant necessity of repairs. Furthermore, as the pressure of the load must necessarily come on one point only at a time, there is a limit to the weight which can be carried successfully without crushing one or several balls and jamming the ball race.

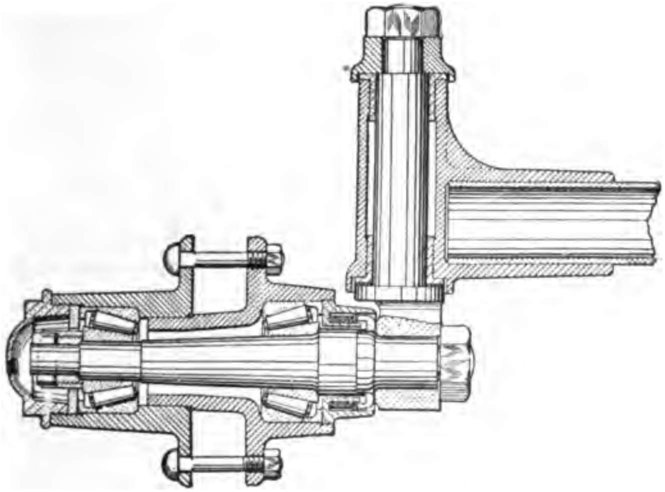


Fig. 128.—Stud Steering Axle showing Hub hung on Conical Roller Bearings. The shape of the bearings serves the double purpose of securing perfect rotative movement in forward travel; also to take up end thrusts.

When the balls are confined by flat cones, heavy pressure upon single points causes crystallization and speedy deterioration. To remedy this defect some builders have curved the cones to fit the balls as nearly as possible, with the result of reducing the wear, but increasing the friction, since there is then no longer a simple rolling action between the balls and cones. Others have adopted the plan of staggering the balls so that they travel upon different surfaces of the cones; but this expedient also involves considerable wear and friction of the ball surfaces, and crystallization follows much more speedily.

The Conditions of Using Roller Bearings.—Very largely from the reasons already enumerated, the roller bearings have come into almost universal use for the road wheels of motor carriages. As stated by a prominent manufacturer of roller bearings, we have it that "for heavy weights it would seem that a greater rolling surface must be obtained before we can have a successful bearing, and yet, combined with this greater rolling surface, there must be a purely rolling action to eliminate the wear that results from rubbing and crystallization."

As stated by a noted authority, the peculiar advantage of the roller bearing lies in the fact that in the ideal conditions there is no relative sliding, and, therefore, theoretically, no friction. As also stated by him, however, there are several difficulties in the way of obtaining the theoretically perfect conditions in practical operation. These are: (1) the concentration of the load upon points; (2) the almost insurmountable difficulty of obtaining truly circular cylindrical rollers; (3) the friction on the surfaces of the rollers themselves; (4) the difficulty of adjustment; (5) the lack of parallelism when the rollers are slightly worn; (6) the difficulty of providing for end thrusts or side pressures; (7) the blows and shocks resulting when wearing has occurred on the surfaces of the rollers. He further explains that to any extent whatever, however small, that the surface of contact deviates from the theoretical or geometrical line, the action between the two surfaces deviates from the theoretically perfect rolling contact, involving sliding or frictional contact proportionate to the deformation of the roller. The principal cause for the breaking of roller bearings, which is so fertile a source of annoyance and disablement to the road wheels of motor carriages, is due to the hammering action resulting when any single roller lacks in the point of uniformity of hardening with its mates, which results in a greater initial strain in its material.

Constructional Points on Roller Bearings.—Given the best possible process available to the practical machinist for the needs of adequately shaping and hardening rollers, the problem of the best construction becomes almost entirely one of proper assembling of the several parts. As shown by the accompanying illustration, the usual method of mounting roller bearings is to enclose them in a suitable case, in which the several cylindrical rollers are separated, so that, rotating on their own axes, their surfaces do not come into contact. It is a very usual practice to include end thrust ball bearings at the extremities of the roller cylinders, so as to still further reduce the wear and friction incident on the rotation of the several cylinders.

One of the most excellent types of roller bearing for motor carriages is the "American" roller bearing, which, as shown by the accompanying illustrations, consists of a set of main rollers intended directly to sustain the weight, and running in races on the hub and on the axle. These main rollers are separated and guided by intermediate separating rollers, whose office is solely that of separating and guiding. These separating rollers are confined between the centres of the main rollers and overlap their ends, their action being entirely rolling. The supports of these separating rollers are had in three rings held in place by the flange ends of the separators and running in narrow beveled grooves in the separators and in the fixed caps which enclose the entire mechanism. The rolling parts are so arranged that the separators engage their supports in perfect harmony with the main rollers, traveling just fast enough to keep up with them in going about the axle, thus avoiding both dragging and pushing.

FIG. 129.—Roller Bearings Enclosed in a Retaining Cage. The bearings are hung to the two end pieces of the cage, being separated by stationary pieces of metal. The inner tube is the rotating axle; the outer, the axle box.

In this type of bearing the end thrust is entirely taken by bevels, on the principle of the flanges on car wheels, this construction involving.that there is no rubbing friction; the action between the ends of the roller and bevels, being purely a rolling one, they are thrust against each other. As claimed by the manufacturers, the separators hold the main rollers far better than any cage could, while the wear upon them is practically negligible, the result being that the main rollers are never allowed to twist around, as is frequenty the case in caged bearings.

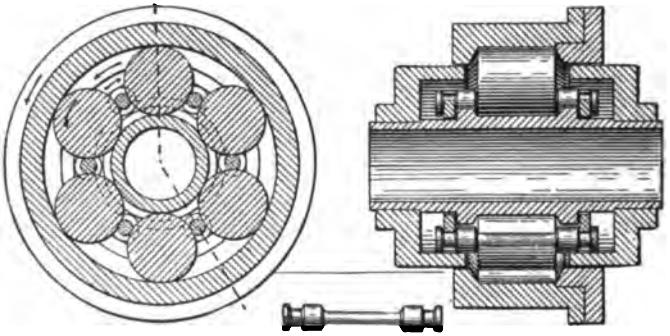


FIG. 130.—Sectional Diagrams of the "American" Roller Bearing. These bearings are beveled at the ends, as indicated, the bevels taking up the end thrusts, and are separated by smaller rollers, one of which is shown below the larger figures. These separating rollers do not come into contact with the rotating axle.

CHAPTER THIRTEEN.

ON THE NATURE AND USE OF LUBRICANTS.

Of Lubricants for Various Purposes.—One of the most important considerations in connection with the operation of a motor vehicle, of any power, relates to the proper lubrication of the moving parts. As is perfectly evident on reflection, it is necessary that all such parts should be supplied with oil or lubricating grease, but it is also a fact, not so well understood, that different kinds of lubricant are necessary to the different kinds of mechanisms.

Of Lubricants for Gasoline Engine Cylinders.—Every reliable dealer in lubricants has a specially prepared grade of oil for a gas engine cylinder, and still another for use in the cylinder of a steam engine, and all agree to the statement, that the kind of lubricant suitable in one case is wholly useless in the other. The primary reason for this distinction is that, as we have seen, the cylinder of a gas engine operates under a far higher temperature than is possible even in a steam engine, and consequently the oils intended for use in the former case must be of such a quality that the point at which they will burn and carbonize from heat is as high as possible. Furthermore, it is essential in a gas engine cylinder that the oil should be constantly supplied, and for the purpose of properly meeting this requirement a number of different kinds of dripping and filtering oil cups have been devised and put into practical use.

Requirements in Gas Engine Lubricants.—As has been repeatedly pointed out by gas engine authorities, the apparently long period spent in finally perfecting the motor was due almost entirely to the fact that the subject of proper lubrication was not fully understood. With the ordinary oils, which are sufficiently suitable for use in the steam engine cylinder, it was impossible to obtain anything like a satisfactory speed and power efficiency, and only when the superior properties of mineral oils were better understood was the present high degree of perfection in any sense obtainable. Even to the present day the question of proper lubricants for gas engines is most essential, and, as has been pertinently remarked, "the saving of a few cents per gallon in purchasing a cheaper grade of oil for this purpose is the most expensive kind of economy imaginable." The general qualities essential in a lubricating oil for use on gas engine cylinders include a "flashing point of not less than 360°, Fahrenheit, and fire test of at least 420°, together with a specific gravity of 25.8 and a viscosity of 175."

FIG. 131.

FIG. 131a.

FIG. 131b.

FIGS. 131, 131a, 131b.—Three Forms of Adjustable Oil Feeding Cup. In the first and second figures, the flow of oil is regulated by the thumb screw at the top. This allows the oil to drip at any required rate. The first figure shows a "sight-feed oil cup," which, as shown, means that the rate and constancy of the feed may be seen through the section of glass tube at the base. In the third figure, the hand-wheel at the top is merely for filling the reservoir, the amount of flow being regulated by the cocks at the base. By regulating the flow by the right-hand cock, the left-hand acts only to open and close the vent, permitting a flow of no more and no less than that determined by the right-hand cock. All three forms are used on automobiles, although the first two are the most common. The first is used for cylinder lubrication.

Some Objections to Organic Oils.—While a number of animal and vegetable oils have a flashing point, and yield a fire test sufficiently high to come within the figures specified, they all contain acids or other substances which have a harmful effect on the metal surfaces it is intended to lubricate. In addition to this, their tendency to gum or congeal under certain conditions of temperature or pressure render them unfit for the purpose of gas engine lubrication.

The Use of Graphite as a Lubricant.—Many authorities strongly recommend the use of powdered or flaked graphite in the cylinders of explosive engines for the reason that this substance is one of the most efficient of solid lubricants, especially at high temperatures. It has been found especially useful in some steam engine cylinders and in general on the bearings and moving parts liable to become overheated. According to several well-known authorities, it is well adapted for use under both light and heavy pressures when mixed with certain oils. It is also especially valuable in preventing abrasion and cutting under heavy loads and at low velocities.

In using graphite as a lubricant, it is positively essential to remember one thing: It is, as said, very useful *for certain purposes*, when mixed with some liquid oil lubricants. However, it is impossible to use it in connection with oils that are to be filtered through the small orifices of constant feed oil cups, as on the cylinders and bearings of engines. The reason for this is that it will not flow through small holes, even when mixed with very thin oil; and the very cooling of a bearing will cause the graphite, mixed with oil, to clog up the oil hole to an extent that may not be remedied by the reheating of the bearing, after the stoppage of the lubricant. On the same account, it is essential that the diameter of the oil conduit to any moving part be ascertained to be of suitable shape and proportions before the use of any solid lubricant is attempted.

The Tests and Qualities of Lubricating Oils.—It is perfectly possible to use an oil having a fire test at the point already mentioned in a gas engine cylinder whose temperature at explosion is nearly four times greater, because with a properly adjusted water circulation the burning and carbonization of the oil is constantly prevented. The heat-absorbing action of the jacket water is also efficient in retaining at the required point the viscosity of the oil—which is to say, the quality of dripping at a certain ascertained rate through a narrow aperture under pressure. This quality virtually refers to the thinness of the oil. A well-known manufacturer of lubricating oils for gas engine cylinders well states the ideal qualities to be sought, as follows: "There is no danger of this oil burning or smoking in the cylinder and thus causing a carbonaceous deposit, which so seriously interferes with the proper running of the engine. We have repeatedly known of this oil, when put into a cylinder which had not been properly cleaned, cutting out the carbonaceous matter that had accumulated from the use of an inferior oil, after which the cylinder would remain clean and polished by the action of the oil alone." Combined with these ideal elements, the claim is made that this particular variety of oil has a very low "cold test," with the very necessary insurance against congealing, and consequent delay and inconvenience in starting the engine. Its resistance to heat is also placed at such a figure that it will not become unusually thin as will some qualities of oil, the reason being that its viscosity is maintained at the desired point.

In choosing lubricants for any of the moving parts of a self-propelled road vehicle it is especially essential to see that the quality of resisting temperatures, both high and low, without change of useful consistency, should be present. An oil that will congeal at ordinary low temperatures, or become thin at ordinary high temperatures, is, of course, entirely unsuitable for this purpose. Furthermore, the quality of flowing freely from well-adjusted oil cups should be assured, since the high speed of automobile engines engendering a constant vibration, affecting more or less the adjustment, involves that the oil supplied should be a subject of constant solicitude. To state the matter in a few words, all competent authorities seem to agree that the conditions of automobile operation require the use of mineral oils on all moving parts and the avoidance of any mixture with animal or vegetable oils, which, although frequently used in stationary engines, cannot but result in inconvenience, not to say disaster, in automobile practice.

Since most manufacturers of motors and vehicles furnish moderately full directions for dealing with the question of lubrication, many of them offering for sale brands of oil which have been carefully tested by themselves, it will be hardly necessary to add more to the principles already laid down. If the automobile driver constantly bears in mind the fact that an oil suitable for one portion of his machinery is not of necessity suitable for every other, and will observe the conditions essential to maintaining the oil used at its proper consistency, he will have little trouble upon this score.

Oil Pumps and Circulation.—With the use of high-speed gasoline engines, it has been found necessary to use a forced circulation of the oil in order to completely lubricate the interior of the cylinder. The most usual method with high-powered multiple-cylinder engines is to employ a positively geared pump to force the oil through adjustable sight-feed conduits to the various moving parts. Such pumps, operating in ratio to the speed of the engine, of course supply lubricant more rapidly as the number of revolutions increases, and slow down as they decrease. Thus, a perfect supply is maintained, as required, on the one hand, and flooding is prevented on the other. There are several efficient types of oil pump on the market, all working on the same principle of forcing the oil to the moving parts in such volumes as may be determined by the adjustment. One or two inventors have produced devices of this kind operated by compressed air forcing the oil out of a tank, the degree of compression being determined by the speed of the engine operating the air pump. Such a device has its advantages, but is not as serviceable as an ordinary oil force pump, and is much more complicated.

Several modern gasoline engines, notably the Locomobile and Winton, have the lubricating apparatus arranged as an integral part of the mechanism. The former, as subsequently explained, uses the splash system, whereby oil fed by gravity from a tank at the level of the cylinder head, flows into the crank case, whence it is splashed over the piston and the wrist and crank bearings. The Winton engine has an oil pump enclosed in the case, and the oil, being forced from this into a special chamber, is distributed to all the moving parts, as required. Other engines use types of multiple oiler, from which the oil is carried to the parts through adjustable sight-feed conduits.

Where horizontal cylinders are used, it is frequently customary to use single grease cups of the general type shown in the foregoing figures, and to control the feed by mechanical pressure from the cap. Such arrangements are less suitable for vertical cylinders, which require oil in large quantities and some degree of exact adjustment in its flow. Indeed, one very useful feature of the oil pump lubrication is that the flow of oil may be kept in ratio to the speed of the engine. This is a very necessary feature, since, with an even flow, flooding is liable to result.

Points on Lubrication.—The first important consideration involved in preparing a carriage for a run is to see that the moving parts are properly lubricated. Every carriage or motor is sold with directions for providing for this necessity, the rate of oil consumption and the quantity being specifically designated. The principal parts which it is particularly necessary to keep thoroughly oiled are the cylinder pistons, the bearings of the crank shafts and fly-wheels, the differential gear drum and the change speed gearing.

Since on most well-built motors and carriages the moving parts are supplied with lubricating oil by means of sight feed oil cups, of familiar design, it is necessary to do no more than to see that the required level of oil is always maintained. As specified by many motor carriage authorities, it is desirable to thoroughly examine and replenish the oil supply in the adjustable feed cups at the end of about every thirty miles of run. Another consideration of importance in this particular is that before replenishing the supply of oil to such parts as the crank case or the differential gear, the old lubricant should be thoroughly evacuated by means of the vent cocks supplied in each case. The reason for this is that, after a run of from twenty to thirty miles, the oil in the moving parts is apt to be largely contaminated with dust and other impurities, which tend to interfere with its usefulness as a lubricant.

CHAPTER FOURTEEN.

GENERAL PRINCIPLES OF GAS ENGINE OPERATION.

Advantages of Internal Combustion Motors.—It has been frequently said that steam is the best available motive power found under ordinary conditions for utilizing the vast expansive energy of heat. At a certain temperature water assumes the gaseous state, and its power of expansion is so immense that, when properly confined, it will displace any movable obstacle in its effort to assume greater proportions; thus furnishing the force for driving machinery. Vaporized water, however, is not the only gas possessing such properties. In certain aspects, it is also not the most convenient medium for transforming heat into motive energy, particularly for small power motors. This is true because the steam engine, as we have seen, requires a boiler or generator to produce the steam and a constant source of heat to accomplish this effect. The consequence is that a large percentage of the heat units employed is actually wasted, even in the best-designed engines. This result is inevitable, because the fuel for combustion, the fluid to be vaporized by heat, and the engine to be driven by the expansive energy are all separate and distinct elements, requiring, frequently, elaborate devices to secure the end of co-operation as a practical working unity. If, now, the expansive energy can be derived direct from the fuel and the ignition effected by an intermittent source of heat, it is obvious that the machine is simplified and the total economy increased. In other words, when some such rapidly-acting expansive force, as is found in the explosion of gunpowder, can be so controlled and utilized as to drive a piston, as a gun throws forth its projectile, or bullet, we have achieved the end of transforming heat into power with the smallest possible waste. In the steam engine one large percentage of heat is wasted in raising the water to the boiling point; another, in maintaining the degree of temperature necessary to continual generation of steam; a third, by being absorbed in the cylinders as a necessary means for preventing a checking of expansion. Furthermore, the chimney draught, requisite to combustion in the heater and as an escape for burned products, acts as a waste in expelling considerable heat through the flue. The nearest approach to the ideal of economy in the steam engine is found in the "flash boiler," as devised by Leon Serpollet, and others, wherein water injected into narrow tubes, already raised to a high temperature by contact with fire, is instantaneously, or explosively, transformed into expansile vapor, to be fed to cylinders, also at a high initial temperature. Even this system involves considerable waste, from the necessity of maintaining the "flash tubes" at the required temperature, between the periods of injection; the wear and corrosion on the metal parts is also excessive. On the whole, its disadvantages are numerous, and render it a very poor substitute for an internal combustion motor, like the modern gas engine.

The Requirements in Explosive Motors.—The internal combustion or explosive engine possesses most of the desirable features, which the steam engine lacks, and realizes many of the requirements of an ideal motor. Its fuel, a hydrocarbon gas or liquid, is properly mixed with air, fed direct to the cylinders, and ignited explosively, so as to be raised instantly to its highest temperature point, by an intermittent source of heat, all in the same small chamber. It is, therefore, merely a cylinder and driving gear, without boiler or furnace attachments; and, on this account, affords a high power efficiency, in proportion to its total size and weight. For use in motor carriages, internal combustion motors must be provided with some device for producing the explosive gas from a suitable liquid; since it is both inconvenient and impracticable to carry it stored in tanks or bottles, which must be constantly charged under high pressure. Such a liquid, moreover, must be one that is readily mixed with atmospheric air, passed through it, or over it, in a specially designed vessel, commonly called a carburetter, or vaporizer, so as to form a true gas with inflammable properties. Several hydrocarbons, such as benzine, gasoline, and some forms of alcohol, are suitable, although gasoline has been most generally adopted for this purpose.

Operation of an Explosive Motor.—The cylinder of a gasoline motor is, as in most gas engines, open at the end toward the crank shaft. Admission for the fuel gas at the opposite end, which is normally closed, is had by mushroom valves operated usually by suction of the descending piston. The piston is, therefore, single-acting, or moved by an impulse from one direction

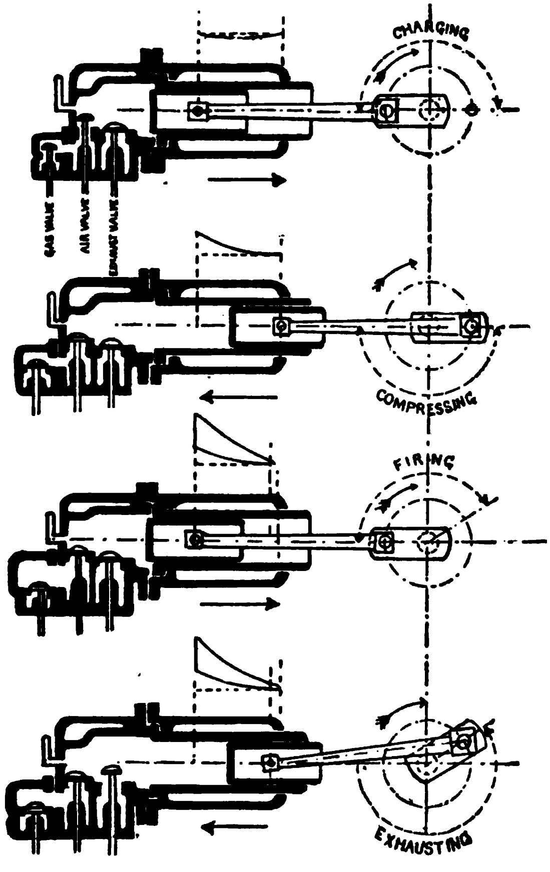


FIG. 182.—The Cycle of an Otto, or Four-Part Cycle, Gas Engine.

only, and is of the "trunk" pattern, having the swinging connecting rod pivoted within. The action of the piston and driving gear, is, thus, entirely positive and automatic, in the sense that there is no pressure whatever outside of the cylinder—as in the steam engine—to effect movements of the parts, when proper valves are opened. An automobile motor is started by turning a crank on the driving shaft a sufficient number of times to carry the gears, cams and valves through the charging, compression strokes, to the moment of ignition, when it will "take up its cycle," and run by the power generated in itself. The cylinder is charged by an out stroke of the piston, creating a vacuum behind it and drawing in the mixture of air and gasoline gas formed in the carburetter. With some carburetters this is too "rich" to burn readily, so a quantity of pure air is also drawn in. With better carburetters the mixture needs no more air. The charge is then compressed by the return stroke of the piston, which act secures complete carburization of the contained air, and reduces it to the proper degree of mixture to be kindled by the igniting spark or other source of firing. This causes it to explode, or to expand suddenly and with great effect, and drive the piston outward again. The fourth stroke, which is the one immediately following the explosion, is known as the "scavenging" stroke, from the fact that the piston, moving back again in the cylinder, expels the products of combustion through exhaust valves which are operated by cams. This process completed, the parts are in position for a repetition of the process; the valves for admitting gasoline gas to the cylinder then being opened again.

The Cycle of a Gas Engine.—These four strokes—two outward and two inward—are called a "cycle," and, as may be readily understood, there is thus only one power impulse for every two revolutions of the fly-wheel. This power stroke also continues while the crank is traveling through half a revolution, or through an arc of 180 degrees. It is also evident that the cam shaft, for operating the valve system of the cylinder, revolves but once for every two revolutions of the crank shaft, with which it is geared. Thus is secured the opening of the charging, or "inhaust," valve, and of the scavenging, or exhaust, at precisely the proper points in the cycle. The operation of a four-cycle gas engine may be understood from this figure: Supposing we have a four-cylinder motor, the cranks of whose four pistons are so fixed that, counting from 1 to 4, we have pistons, cams and valves in positions representing the four cycles. That is to say, the first cylinder would be performing the inhaust stroke; the second, the compression; the third, the explosion; the fourth, the scavenging. In such an engine the crank would be turned by a steady impulse, since in some one of the four the explosion would be due in every 90 degrees of its rotation. Also every one of the four cycles would be taking place contemporaneously. Thus, may be understood the process essential to the operation of a gas engine of the "Otto," or "Beau de Rochas" four-cycle type.

Two-Cycle Engines.—Practically all carriage motors are built for the four-cycle system, which requires two complete revolutions of the fly-wheel to perform the four necessary acts involved in the use of gas as a motive power. There is, however, a method of accomplishing the same results in one revolution, and it is, accordingly, known as the two-cycle system. It uses one rotation and two strokes, the functions of the two omitted strokes being provided for by certain peculiarities of construction. Its essential features are as follows: (1) An enclosed crank case, such as is also used on most vehicle motors, is fitted with a valve geared to open and admit fuel gas at the front, instead of at the rear of the piston, on the first inward stroke of the piston. (2) The inhaust and exhaust ports of the cylinder are located at points about midway in its length, so as to be uncovered by the piston in its downward stroke. The exhaust being reached first, the

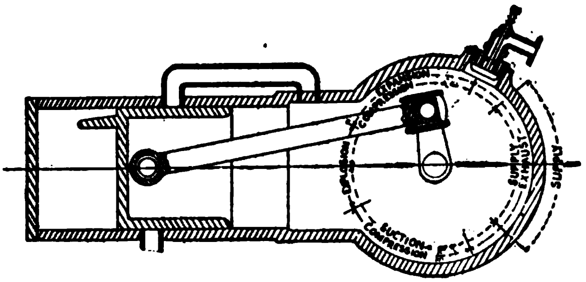


FIG. 133.—Diagram of the stages of a Two-Part Cycle Gas Engine. The out-stroke is from left to right; the in-stroke from right to left. The inner circle around the crank shows the stages of compression, supply, suction, which take place within the crank case in front of the piston. The outer circle shows the stages of explosion, expansion, exhaust and compression, which take place behind the piston in the combustion space of the cylinder.

products of combustion start to leave the cylinder, partly through their tendency to expand, before the fresh supply begins entering from the enclosed crank case. (3) At the end of the piston, and so placed as to come opposite the entry port for the fresh charge, when it is opened, is a longitudinal plate or screen, which deflects the new gas to the top of the cylinder chamber, thus causing it to assist in the work of expelling the burned products. This work is further completed as the piston starts on its return stroke.

The four acts, admission, compression, ignition and scavenging, are thus accomplished during one revolution of the fly-wheel by the use of two chambers. The fuel gas is admitted to the closed crank case during the inward stroke of the piston, at the completion of which the supply valve is closed. On the return, or outward, stroke this gas is suitably compressed to about five pounds to the square inch, which pressure causes it to rush into the cylinder the moment the supply port is opened. When both the supply port and exhaust port have been closed by the inward stroke of the piston, the contained fuel gas is still further compressed, and is ready for ignition, as the piston reaches the end of the cylinder. The next outward stroke is under power impulse, as indeed is every outward stroke on the two-cycle arrangement; each inward stroke accomplishing the results of supply and cylinder compression, and each outward stroke, the results of ignition, exhaust and recharging.

Two-Cycle Motors for Vehicle Use.—While it would seem from the theory of the two-cycle motor that it should be capable of a higher degree of power as well as a greater speed—features which should render it the ideal motor for vehicles—it is, nevertheless, true that its practical performance is otherwise. It is a very satisfactory type of engine for low speed purposes, and in such conditions will develop, as some claim, a power fully 50 or 60 per cent. greater than with a four-cycle engine of the same dimensions. This statement is questioned by other authorities, but, as may be readily understood, an engine giving a power impulse stroke in every revolution should, theoretically, have twice the available power capacity of one having a power stroke in every two revolutions only. This would undoubtedly give about the practical percentage of superiority named above. At high speeds, such as are contemplated in the construction of motor carriages, the trouble with the two-cycle motor is that, all the functions of inhaust, compression, ignition and exhaust being performed in a single stroke of the piston, sufficient time is not allowed for the expulsion of the burned gases, with the result that the cylinder "chokes itself up," as the saying is, and its contents fall below the explodable point, stopping the engine. It is thus estimated that, while a four-cycle engine of a given horse-power will run at as high a speed as 1,200 or 1,500 revolutions per minute, a two-cycle engine of the same power can make no more than 300 or 350 revolutions. The same defect in operation prevents the two-cycle motor from attaining the power efficiency, otherwise seemingly involved in its constructional theory. It is on these accounts that the two-cycle type of motor has thus far proved unavailable for automobile purposes, where the four-cycle engine has proved eminently effective.

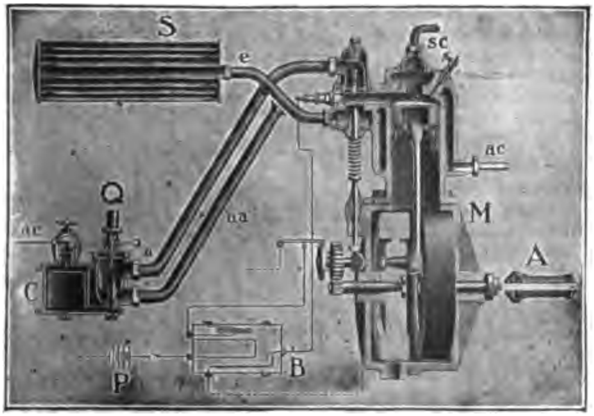


FIG 134.—Diagram showing the Essential Features of a Typical Carriage Motor, as used on the De Dion Vehicles. M is the motor; C, the carburetter; S, the muffler; P, the sparking battery; B, the induction coil and condenser; Q, the pipe admitting pure air to the carburetter; *aa*, pipe for bringing hot air from around exhaust pipe; *e*, exhaust into muffler; *a*, pipe admitting gas to cylinder; *ae*, gasoline feed to carburetter; *ac*, port for admitting water to the jacket space of the cylinder; *sc*, exit port from the water jacket.

The Essentials of a Vehicle Motor.—Every gasoline vehicle must carry its supply of fuel spirit in a tank or receptacle with suitable outlet valves, through which it may be drawn as required. The motor proper consists of three parts; the carburetter, or vaporizer, in which the liquid hydro-carbon is transformed into vapor; the cylinder, to which it is admitted by suction, mixed with a suitable supply of pure air, compressed and ignited, and an ignition apparatus for producing the spark or hot surface essential to explosion. So far as the operation of the cylinder is concerned there are two general types of engine:

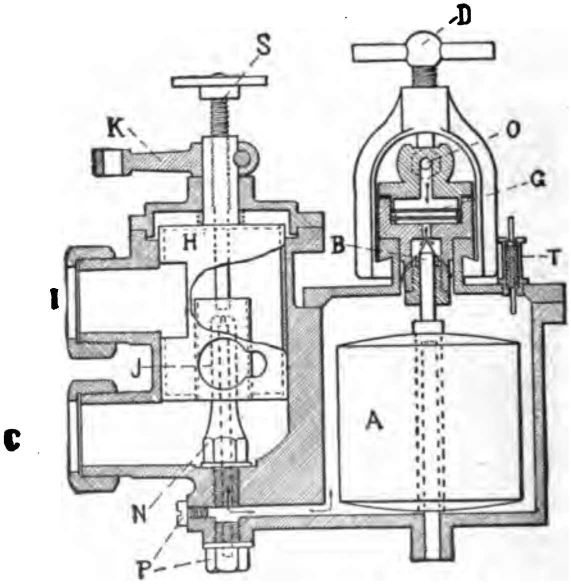


FIG. 185.—Section through a typical Float-Feed Carburetter. This particular device is the one shown in the previous cut. Here A is the hollow cylindrical float; B, the spindle of the needle valve; C, tube for admitting hot air around base of spraying nozzle; D, adjusting screw for the needle valve; H, adjustable air valve; I, outlet for fuel mixture to cylinder; J, adjustable opening for air; K, arm for attaching throttling lever; N, spraying nozzle; O, P, screw caps on channel fromfloat chamber; S, adjusting screw for regulating gasoline spray; T, air vent; G, filtering gauze.

scavenging engines, in which all the burned-out gases are expelled from the cylinder, and non-scavenging engines, so constructed and operated that a certain portion of these residua are retained in the clearance.

There are two general types of carburetter: surface carburetters that operate by evaporation, and float-feed carburetters, or sprayers. A third variety of carburetting device is recognized by some authorities in the type of gasoline outlet valves, such as the James-Lunkenheimer, or the Winton, in which the gasoline outlet is opened with the air valve, permitting a quantity of gasoline to pass in proportion to the time of opening. This is mixed with the air passing through.

There are several methods used for igniting the charge in a gas engine cylinder. Among them may be mentioned the gas jet and hot tube of the Otto engines; the hot head of the Hornsby-Akroyd and the hot wall of the Diesel motor. Although vehicle engines of the Daimler type still retain the hot tube ignition, most of them operate with an electric spark. Electric sparking devices are of three general types: jump sparks, wiping sparks and break-contact sparks. The first variety is usually produced from a high-tension current—one emerging from the secondary circuit of an induction coil, the primary circuit being made and broken at timed intervals so as to produce a spark between two points in the secondary, as the circuit is thus broken. The two latter varieties of spark are usually produced direct from the primary current. Many authorities consider the break-contact spark as a variation of the ordinary wipe spark, in which the contact has been so reduced as to escape the great wear occasioned by constant rubbing of metal surfaces. The electric cur-

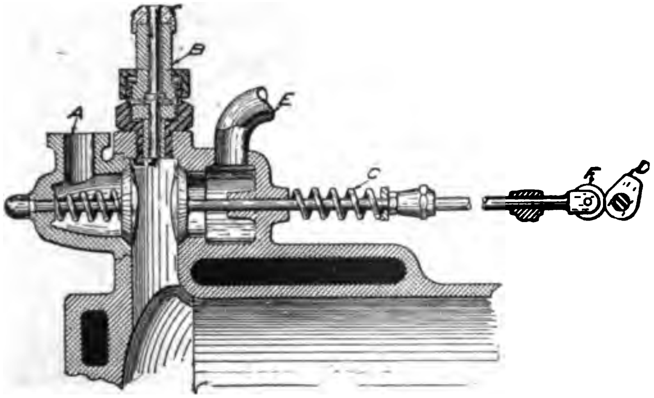


FIG. 136.—Detail Diagram of the Valves and Attachments of a Gas Engine Cylinder. A is the inlet port behind inlet valve held in its seat by a tension spring; B, the spark plug for "jump-spark" ignition; C, the push rod and compression spring of the exhaust valve; D, the cam opening the exhaust; E, the exhaust port; F, the roller at end of valve rod bearing on the cam, D.

rent for ignition purposes may be generated by ordinary chemical cells, or by a magneto-generator or small dynamo.

The cylinder is supplied and exhausted by ports closed by poppet or mushroom valves, held in position by springs. The exhaust valve is positively operated by cams geared to the main shaft; the feed valve is generally operated by suction of the piston, although some motors have it also positively geared. Another important function in a gas engine is that of cooling the cylinder; for, unlike the steam cylinder, which is often steam-jacketed and otherwise protected to prevent falling temperature from checking expansion, the gas engine cylinder must be regularly cooled, so as to be maintained at a temperature sufficiently low to prevent premature ignition of the charge and consequent disarrangement of the cycle. It is also necessary to avoid such high degrees as would cause carbonization of the lubricating oil, although oils are produced that will give a fire test of over 600°, a point sufficiently high for most well designed motors. With inferior grades of lubricating oil, and insufficient cylinder-cooling devices, the danger of the engine "grinding itself to pieces" is generally to be feared. This is one excellent reason, as stated by several authorities, why an

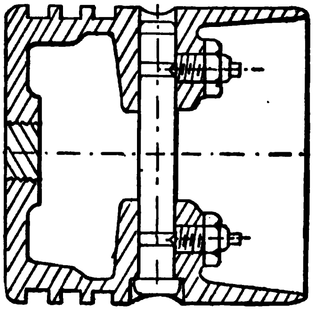


FIG. 137.—Section through a typical Trunk Piston for a Gasoline Engine. Around the circumference, near the rear end, are three circular grooves for inserting the packing rings. Through the central diameter is a perforation for admitting the piston pin, which is held in place by square-headed screws.

The proportions of the piston pin must be carefully calculated for the load it is intended to bear. In general, the length of the piston pin should be equal to that of the crank pin, and its diameter such as to bear an average of 750 pounds for each square inch of its projected area. As given by Roberts, the proper diameter of the pin may be determined as follows:

$$\text{Diameter} = \frac{\text{Cylinder area} \times \text{M. E. P.}}{750 \times \text{length of pin.}}$$

air-cooled cylinder is insufficient for vehicle motors of more than two horse-power. It does not cool rapidly enough. There are two methods of cylinder-cooling: air-cooling by transverse, or longitudinal ribbing, by radiating pins or by rotary fan; and water cooling, by circulation of water or other liquid through jacket spaces around the cylinder chamber.

The operation of the engine, as regards both speed and power, is controlled in two ways: by a centrifugal governor on the main shaft, or by a throttling lever at the driver's hand. The mechanical governors are of two kinds. In the first we have those operated on the "hit-and-miss" principle, which involves some form of cam and push rod mechanism to be thrown out of gear at high speeds and cause the engine to *miss* charge or exhaust by opening or closing the exhaust valve, or closing the feed valve during one or several strokes. Such a variety of governing mechanism may also be geared to open the circuit of the sparking current, thus preventing timed ignition. The latter method, however, involves short-circuiting the battery and is seldom used where chemical cells supply the current. A second theory of governor regulation involves mechanical operation of a throttle valve, either for

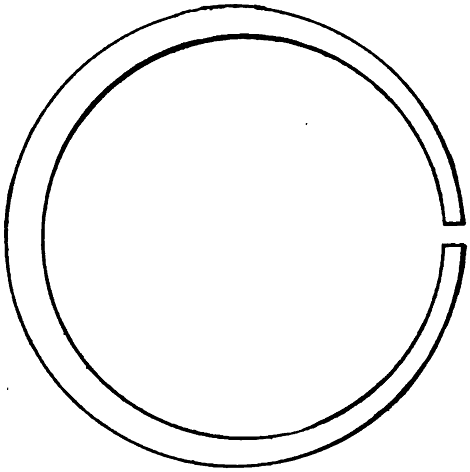


FIG. 138.—Piston Packing Ring for a Gas Engine Cylinder. The inner and outer circumferences are eccentrically arranged, so as to permit of considerable expansion under heat.

the pure gasoline supply or for the mixture leaving the carburetter under piston suction. The latter of these is the preferable under most conditions since, unlike the former, it seldom allows the feeding of a mixture that may not be exploded, as must be the case if the original source of gasoline is throttled.

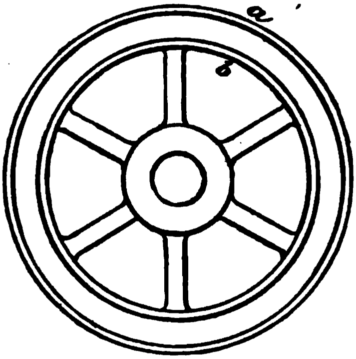


FIG. 139.—Fly-Wheel of an Engine. Since the fly-wheel of a gas engine serves the function of "storing up" energy and equalizing the conditions of operation, its proportions must be carefully calculated. As given by Roberts, the proper weight for a given engine may be found as follows:

$$\text{Weight} = \frac{\text{I. H. P.} \times 111{,}600{,}000{,}000}{(\text{wheel diameter})^2 \times (\text{R. P. M.})^2 \times \text{E}}$$

in which E is the co-efficient of permissible unsteadiness. The same authority says that the length of the hub should be between 1.5 and 2.5 the diameter of the crank shaft; and, that the outside diameter of the wheel should be between 4 and 5 times the stroke length, which, with a rim-speed of 6,000 feet per minute, which is the practical maximum, gives the formula:

$$\text{Diameter} = \frac{1910}{\text{R. P. M.}}.$$

Here, 1910 is the approximate quotient between 6,000 and 3.14159, or the ratio between the circumference and diameter of a circle.

Construction of the Cylinder and Piston.—The cylinder of an internal combustion motor is open at the front and has the valves for admitting and expelling the fuel at the rear. The piston is always of the "trunk" pattern—a cylindrical box somewhat shorter than its stroke and in length usually about one-third more than its diameter. For smaller types of motor the side walls of the piston are about 5-16 inch in thickness, never less, and the rear end wall is, as a usual thing, somewhat more. The cylinder and piston are machined so as to give a play of about .001 inch, thus allowing the piston to move easily in the length of the bore. In order to further ensure a good fit, three, and sometimes four, iron rings are inserted in grooves cut in the circumference of the piston near the rear end, and held in position with dowel screws. These piston rings are so made that the external and internal circumferences form eccentric circles, as shown in the accompanying figure. They are also cut open at one point. By this means is secured a play in the grooves of at least 1-32 inch, which allows for expansion and lengthening of the rings under heat of the ignited fuel. The rings are sprung on over the junk rings between the grooves, and when in place should have an outside diameter which can fit the cylinder bore. This bore is usually one or two-thousandths of an inch larger than the outside diameter of the piston. Owing to the fact that the heat produced in an explosive motor cylinder is greater than in a steam cylinder, a slight play is allowed for the rings at the sides.

The Crank and Driving Gear.—In the disposition of the crank and driving connections, the explosive motor differs again from the steam engine. The piston rod in the steam engine slides through the stuffing box in the cylinder head, and the crank is attached to the end at the cross head, which works between guides. The gas engine cylinder, being open at the forward end, has no head or stuffing box and no piston rod proper; in fact, the crank and piston rod are combined in one. The crank is hung on the gudgeon pin fixed midway in the length of the hollow trunk piston, and works on the crank shaft, upon which the fly wheel is secured. Although, as we have already seen, the small steam engines for vehicle use dispense with the fly wheel, such a balance is positively essential in a gas engine of any size or power. The reason for this lies in the fact that the ordinary four-cycle motor, having but one power stroke in every two revolutions of the crank shaft, requires a heavy fly wheel to counteract the speed fluctuations and to "store up" energy sufficient to carry the rotation through the three idle strokes of exhaust, inhaust and compression. For this reason gas engine fly wheels are made much heavier than those designed for steam engine use. Many gas and gasoline motors are also made with two fly wheels, one on either side of the crank pin, which is in fact attached midway on a radius of the two wheels, or "discs," as in all enclosed crank case motors.

CHAPTER FIFTEEN.

THE PRESSURE, TEMPERATURE AND VOLUME OF GASES IN A GAS ENGINE.

Operation of Explosive Motors.—Since an explosive motor operates through the rapid expansion of gas under conditions of combustion, calculations to determine its power and other capacities must be based on considerations of volume, pressure and temperature. As may be readily understood, either of these elements may be taken as a basis for calculations including the others, since, other things being equal, the degree of temperature produces the volume, or the relative tendency to expansion, and the increase of volume to a certain point involves increase of pressure. Thus it follows that the whole cycle of a gas engine is characterized by a proportionate increase, the factors of variation being considered, in the elements productive of power and motion. At the aspirating, or inhaust, stroke, the outward movement of the piston, by creating a partial vacuum, causes the feed valves to open under atmospheric pressure, thus indicating that the pressure within is lower than that of the atmosphere without. At explosion the volume and temperature are raised, and at the end of the scavenging stroke, the exhausted products of combustion are expelled with a force indicative of a pressure several times greater than the atmosphere. The inhaust stroke being completed, and the feed valves closed by force of a spring, there is no considerable increase in volume and pressure due to contact with the hot cylinder walls, nor yet from the residuum of burnt products in the clearance or combustion chamber, although, owing to the valve spring, the pressure of the contained gases is below one atmosphere. As shown by average indicator tracings, the rise in pressure during the inhaust stroke is from a negative point to generally about 13.50 pounds to the square inch. So soon, however, as the compression stroke begins, the indicator tracing shows a steady rise from 14.7 pounds to the square inch, or normal atmospheric pressure, to 65 or 70 pounds at the completion of the stroke, the rise in temperature being on an increasing ratio during the latter half, although during the first half approximately regular. That the superheated residua of combustion in the clearance, being again compressed, are effective in producing the rapid rise at the end of the stroke is suggested by the fact that the figures for both pressure and temperature are, other things equal, greater for a non-scavenging than for a scavenging engine. At the end of the compression stroke the gas mixture in cylinder has attained its greatest density, also its greatest pressure and temperature previous to combustion. It is then ready for firing, which is accomplished very shortly before the piston begins the second out-stroke, the explosion serving to bring the gas to the maximum point for volume, pressure and temperature alike. In fact, the effect, as shown by thermometer and indicator tests, is that the temperature in a gas engine cylinder rises during this stroke from between 500 and 700 degrees, absolute, as noted when the engine is running at good speed, to between 1,500 and 2,000 degrees, on the average, and the pressure from an indicated 65 or 70 pounds to 200 or 230 pounds per square inch. The fall in both particulars is equally rapid during the succeeding in-stroke, when the burnt gases, under impulse from the piston, are expelled through the open valves. At the completion of this exhaust stroke, accordingly, the same cycle of pressure and temperature transitions is begun again, all superfluous heat units having been carried off in the exhaust and through the cylinder-cooling system.

Regarding the time of firing practice differs considerably. Generally, as stated above, it is slightly before the beginning of the power stroke, in order to allow time for the burning gas to begin expansion. Slow-speed motors are generally fired very slightly after the dead centre. With high-speed motors it varies from about 5 degrees after dead centre to 30 or 40 degrees ahead (as measured on the crank). With a large spark, hot motor and well-mixed fuel, the advanced spark is seldom set more than 15 or 20 degrees ahead.

Principles of Pressure and Temperature in Gases.—As we have already explained in the section on steam engines, a leading property of gases is that, the temperature remaining about the same, an increase in volume involves a corresponding decrease in pressure, and, that to maintain even a constant pressure in an expanding gas, the temperature must be raised on a steadily increasing ratio. In other words a given cubic content of expanding gas, at a constant temperature, shows a lower pressure per square inch as the expansion progresses, and, in order to obtain a given total, original, efficient pressure the cubic content of the cylinder must increase with the expansion. On the other hand, if a given cubic content of gas be compressed to half its normal volume, without involving an accompanying increase in temperature, the pressure is doubled. In either case, an undue increase of temperature operates to neutralize the stated principle.

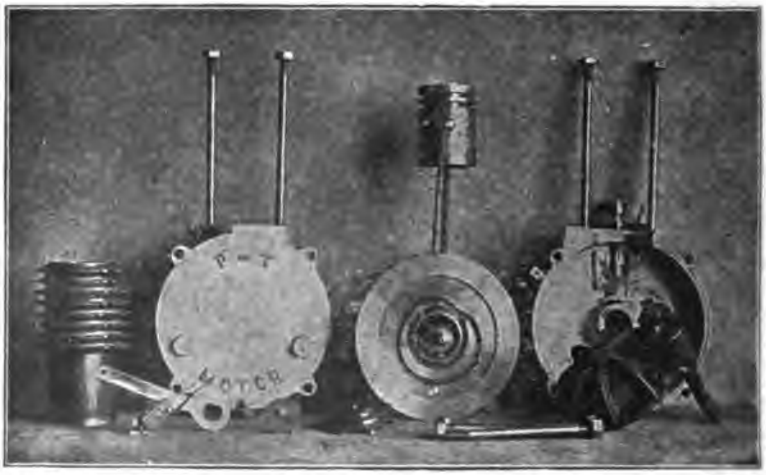


FIG. 140.—The Parts of an Air-Cooled Vehicle Motor, shown for an efficient make of bicycle gasoline engine. The cylinder, carrying radiating ribs, is shown at the left. Next is the outside view of one-half of the crank case; then the trunk piston with the piston rod attached to the crank discs. At the right of the cut is the inside view of the other half of the crank case, with the cylinder head lying in front of it. The crank disc, or fly wheel, shows the double eccentric cam groove for operating the exhaust valve rod, which was a distinctive feature of the earlier Daimler gasoline engines.

Fom these facts we may deduce the principles that:

1. The pressure of a gas varies inversely with the volume and directly with the temperature.
2. The volume of a gas varies inversely with the pressure and directly with the temperature.

3. The temperature of a gas varies directly with both the pressure and the volume.

To state these principles in another way, we may say:

1. An increased pressure involves a decreased volume or an increased temperature.
2. An increased volume involves a decreased pressure or an increased temperature.
3. An increased temperature involves an increased volume and an increased pressure.

As the operative conditions in a gas engine are immensely irregular no formulæ can precisely express the proper temperature, volume or pressure for theoretical situations. Since, however, the attributes of the fuel gas at various points in the cycle series are in direct proportion to the dimensions of the cylinder, the length of the stroke, the cubic content of the clearance, and the percentage of atmospheric air in the explosive mixture, very exact figures may be found to express the power and capacity of any particular engine.

Proportionate Figures for Temperature and Pressure.—In the operation of the explosive motor the fuel gas is confined within the cylinder, so long as its properties are significant in calculation on power and speed. The figures for the total cylinder content being then determined, we have a constant standard of comparison for calculating the pressure and temperature of a given mixture of gas and air under the several cycular conditions. For, although the contained gas ocupies the same cubic content at the beginning of the compression stroke and at the end of the firing stroke, it is obvious that its proper volume is vastly increased at the latter moment, as indicated by the raised pressure and temperature figures. But, following the principles laid down above, we find that the figures are regular and proportionate as between the initial and final volumes, pressures and temperatures.

The following formulæ express these conditions:

Let P' be the initial pressure.
Let P'' be the final pressure.
Let T' be the initial temperature.
Let T'' be the final temperature.
Let V' be the initial volume.
Let V'' be the final volume.

Then:—

$$\frac{P' \; V'}{P''} = V''; \qquad \frac{P' \; V'}{V''} = P'';$$

$$\frac{P' \; T''}{T'} = P''; \qquad \frac{T' \; P''}{P'} = T''.$$

From these formulæ we may deduce the obvious rules that:

1. The final volume divided by the initial volume is equal to the final pressure divided by the initial pressure; or, the final volume divided by the initial pressure is equal to the initial volume divided by the final pressure. Having reduced this to a definite basis we have it that the final volume equals the quotient found by dividing the product of the initial pressure and initial volume by the final pressure.

2. On precisely similar lines, the final pressure equals the quotient found by dividing the product of the initial pressure and initial volume by the final volume.

3. The final pressure also equals the quotient found by dividing the product of the initial pressure and final temperature by the initial temperature.

4. The final temperature equals the quotient found by dividing the product of the initial temperature and final pressure by the initial pressure.

In calculating practical figures the initial volume, pressure and temperature may be those taken at the beginning of the compression stroke, when the figure for volume is at the highest point and the figures for pressure and temperature are at the lowest points, independent of any external agency that can modify them. The formulæ given above may be used for calculating between the initial point and any subsequently following by comparing its figures with the figures found at that given point. In practice, however, they are always used in connection with the absolute figures for pressure and temperature, next to be described.

Absolute Figures for Pressure and Temperature.—As is obvious, the proportions of the cylinder content, stroke and clearance are always constant and known. Those for temperature may be found on the thermometer scale: those for pressure, by the indicator gauge. In practice, however, it is customary to use "absolute figures," as they are called, which represent the sum of the thermometric or the gauge figures with certain constants determined by calculation and experience. Thus the absolute pressure is the gauge pressure plus 14.7, which is the atmospheric pressure in pounds per square inch. The absolute temperature is the sum of the sensible thermometric temperature and the constant 461. This latter figure, which is properly expressed as 460.66, represents the total number of degrees on the Fahrenheit scale from 32° below the freezing point of water to the absolute zero of temperature, as calculated by the expansion ratio of gases.

FIG. 141.—A Daimler Single-Cylinder Motor intended for Stationary Use. Attached to the head of the water-cooled cylinder are the gasoline chamber and carburetter. The lubricating cup is shown immediately below. The exhaust valve, not shown, is operated by a cam on the secondary shaft, geared to the crank shaft, as may be seen within the fly-wheel. In essential particulars this motor is identical with those used for vehicle propulsion; the method of mounting being, of course, different.

Thus, in calculating temperatures in gas engine practice, the custom is to count from absolute zero. For example, instead of 64°, writing 525°, and instead of 32°, writing 493°, or, more correctly, 492.66°. The utility of this system lies in the fact that, as a gas has been found to expand by 1-273 of its original volume for each degree, centigrade, or by 1-461 for each degree, Fahrenheit, of increased temperature, we have by the use of absolute figures an approximate expression for both increased heat and increased volume in the same number.

On a scale giving as a unit one part out of 493 for 32°, and one part out of 525 for 64°, we have a co-efficient of expansion that is capable of ready verification. The same line of reasoning holds good for pressure calculations, which start from a theoretical zero at the beginning of the inhaust stroke, and are, theoretically, reducible to atmospheric conditions only by the addition of the 14.7 pounds per square inch. For this reason tables giving the pressure series for gas cylinders of various proportions at the end of the compression stroke most often start from the theoretical one pound pressure per square inch, which column gives the figures to be multiplied by the ascertained pressures at the beginning of the compression stroke for any given motor.

Measuring the Conditions of Operation.—The factors entering to vary the figures, with the same initial pressures in different engines, are the ratio of compression and the percentage of the clearance volume, as compared with the total cylinder volume. The ratio of compression is found to be equal to the quotient of the total volume of the cylinder from the beginning to the end of the stroke, including also the clearance, divided by the volume of the clearance, which, as is evident, is never decreased during any portion of a stroke. The percentage of the clearance volume is similarly found by dividing the volume of the clearance by the volume of the piston displacement: in other words, it is the quotient of the cubic content of the clearance, from the rear of the cylinder to the rearmost reach of the piston at the end of an in-stroke, divided by the cubic content of that portion of the cylinder included between the inmost point of the in-stroke and the outmost point of the out-stroke, as indicated by the position of the rear end of the piston at those two points. Having ascertained these proportions for any given engine the *absolute figures* for operating pressure and temperature may be readily found. Thus, in order to find the pressure per square inch at the end of the compression stroke, it is necessary only to multiply the figure corresponding to an engine with the given compression ratio and percentage of clearance by the ascertained gauge pressure at the beginning of the stroke, or any other required pressure at the same point. Thus the initial pressure at theoretical unity for a cylinder having a compression ratio of 3 and a clearance percentage of 50 is 4.407, which multiplied by 13, the gauge or desired pressure, gives 57.29; by 13.2, gives 58.17; by 13.5, gives 59.49; by 14, gives 61.69; by 14.7, gives 64.78.

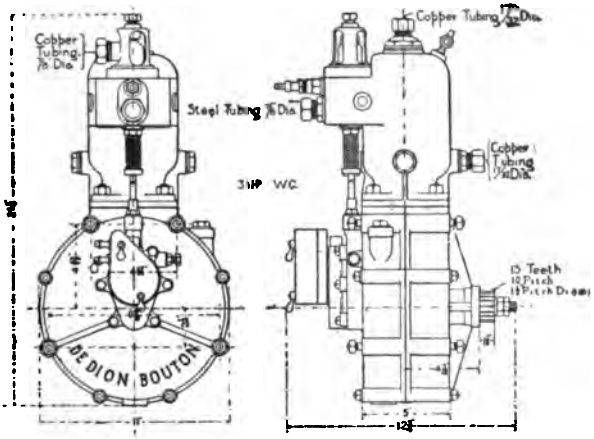


Fig. 142.—Rear and Side Elevation of a De Dion Water-Cooled Carriage Motor, showing method of joining the two halves of the crank case and bolting them to the cylinder. As indicated, also, the water-jackets, cylinder head and valve chamber are cast integral with the cylinder.

The compression temperature is similarly determined by multiplying the found or required absolute temperature at the beginning of the stroke by the figure for one degree for a type of engine having the same compression ratio as the one in question. Thus, for an engine having the ratio at 3, the theoretical initial temperature is estimated as 1.46°, which, for an initial absolute temperature of 525° gives 766°, and for 560° gives 822°.

Since these processes are of importance in calculating the power of a gas engine, it is well to enter into the general principles involved, as introductory to a more extended study of the subject. The cubic content of a cylinder, together with the content of the stroke and clearance areas may, of course, be calculated by knowing the diameter and length of the cylinder and the length of the stroke. A more practical method for unskilled mathematicians and mechanicians is that suggested by E. W. Roberts in his "Gas Engine Handbook." As described by him the process is, briefly, to turn the crank to a dead center and close the valves, and then fill the cylinder with water. By altering the position of the piston rod from in-stroke end to out-stroke end, the cubic content of both clearance and total cylinder may be accurately estimated. The water having been weighed before pouring it into the cylinder, the weight of that left over is a ready indication of the weight of that within. Now, as is well known, water at a temperature of 39.1° weighs 62.5 pounds per cubic foot. Thus, when the temperature of the water is higher than 39.1° its weight per cubic foot may be found by the following formula, in which T is the thermometric temperature, 461, the constant of absolute temperature, and 500, the absolute temperature of water at 39.1°.

$$\frac{62.5 \times 2}{\frac{T + 461}{500} + \frac{500}{T + 461}} = \text{Weight per cubic foot.}$$

This formula is particularly convenient where the cylinder has a spherical or enlarged combustion chamber, which would involve mathematical processes of considerable intricacy to properly estimate its content. As it is, the only requirement is that we substitute the ascertained temperature figures for T wherever it occurs; reduce the factions to a common denominator, and perform the indicated additions and divisions.

Application of the Formulæ.—Taking the fuel gas at constant volume—this is theoretically the condition in the gas engine—and raising its temperature through a certain number of degrees involves a proportionate increase in pressure. Thus, knowing the initial and final temperatures, we may derive the gauge pressure of compression, since the pressure of a gas is in direct ratio to the temperature. If from an absolute initial temperature of 525° (64° plus 461) we have a final temperature of 2161° (1700° plus 461), the increase or acquired temperature is 1636°. Beginning at 525°, the ratio of increasing volume and temperature is 1-525th, or .0019047. Then, multiplying together the ratio thus found, the acquired temperature and the absolute initial pressure (14.7), we have the gauge pressure of compression, which is 45.80 pounds to the square inch. As may be readily demonstrated by performing the same operations with other initial and final figures, the initial presure is in strict proportion to the volume and temperature. Other things being equal, therefore, it might seem reasonable to lay down the rule that, the higher the pressure of compression, the greater the rise in temperature at the point of ignition and, consequently, the greater the efficiency in units of work. Accordingly, we find that, while in many early gas engines this pressure was very much below fifty pounds to the square inch, with the more modern and improved patterns it strikes an average in the neighborhood of seventy pounds. It must not be forgotten, however, that this rule has very definite limitations, and that beyond a certain point of increased compression pressure the efficiency ratio begins to decrease rapidly. As has been already suggested, the ratio of compression is to be calculated on the proportions existing between the clearance, or combustion chamber, and the total effective length of the cylinder, as shown by the area of the piston sweep, or stroke. Consequently a decrease in the clearance content involves, to a certain point, a proportionate increase in the ratio of compression, with commensurately higher temperature and efficiency. Thus, applying the rule for calculating the compression ratios of two cylinders, in which the clearance and total content are in proportion of 2 to 4 and 1 to 4, respectively, we derive the following expressions:

$$\frac{2+4}{2} = 3 \qquad \frac{1+4}{1} = 5$$

Such a result may come either from decreasing the clearance, increasing the stroke sweep, or varying the figures in both particulars.

Taking a theoretical one pound pressure and one degree temperature, initial, we have the following figures for varying compression ratios in non-scavenging engines, derived as above:

With a ratio of 3, we have 4.407 for pressure and 1.4689 for temperature; with 4, we have 6.498 and 1.6245, respectively; with 5, we have 8.783 and 1.7564; with 6, in the same way, 11.233 and

1.8722. These figures, multiplied by the ascertained initial pressure and temperature in any particular engine of the same ratio, will give the proper figures for that engine. Fractional figures range between those given. In a scavenging engine—one that is constructed to expel the whole of the burned products, although never fully accomplishing the result in practice—the clearance ratio is virtually an expression for the total cubic content swept by the piston. Since, then, the stroke-sweep of an engine is the one consideration, as compared with engines of different proportions in this particular, we should have, theoretically, about the same degree of pressure and temperature as are given above. As estimated by several authorities, however, the figures vary somewhat. Thus, as before, for scavenging engines at the theoretical unity for initial pressure and temperature, with a ratio of 3, we have 4.264 for compression pressure, and 1.4213 for compression temperature; for 4, we have 6.233 and 1.5707, respectively; for 5, we have 8.368 and 1.6737; and for 6, we have 10.646 and 1.7742. The figures seemingly indicate a difference of rise in temperature and pressure due to the recompression of burned gases that is about .2 degree for a compression ratio of 3, and .1 degree for a compression ratio of 6, as found in the former type of engine over the latter. If this conclusion is correct, as some authorities seem to question, we find that the heat efficiency of the burned gases, as found at the end of the compression stroke, is in inverse proportion to the length of the stroke in any given engine, indicating the greater loss of heat units to the jacket water of the cylinder in the motor of proportionately longer stroke. Since, then, the quantity of burned and expanding products is naturally smaller in the scavenging cylinder than in one of the other type, we can readily understand how that the figures for compression pressure and temperature are higher for the latter than for the former, as possessing an absolutely greater internal efficiency for heat and pressure.

Figures on Compression Pressure.—On the matter of compression figures this quotation from Hiscox will suffice:

"It has been shown that an ideal efficiency of 33 per cent. for 38 pounds compression will increase to 40 per cent. for 66 pounds, and 43 per cent. for 88 pounds compression. On the other hand, greater compression means greater explosive pressure and greater strain on the engine structure, which in future practice will probably retain the compression between the limits of 40 and 60 pounds.

"In experiments made by Dugald Clerk with a combustion chamber equal to 0.6 of the space swept by the piston, with a compression of 38 pounds, the consumption of gas was 24 cubic feet per indicated horse-power per hour. With 0.4 compression space and 61 pounds compression, the consumption of gas was 20 cubic feet per indicated horse-power per hour; and with 0.34 compression space and 87 pounds compression, the consumption of gas fell to 14.8 cubic feet per indicated horse-power per hour—the actual efficiencies being respectively 17.21 and 25 per cent. This was with a Crossley four-cycle engine."

FIG. 142a.—The Knox Single-Cylinder Runabout. A typical American gasoline carriage.

CHAPTER SIXTEEN.

THE METHODS AND CONDITIONS OF GAS ENGINE CYLINDER COOLING.

Rate of Gas Consumption.—As given by several authorities, who base their calculations upon engines possessing the most favorable conditions in the respects above enumerated, and using the fuel best suited to the end in view, the average of gas consumption per horse-power per hour is 20 cubic feet, although, as may be readily understood, such figures vary with the kind and quality of fuel and the proportions in such matters as are mentioned by Hiscox, as above quoted. There are, however, other considerations entering into the judgment of ideal efficiency and some of these we will proceed to treat.

The Conditions of Efficiency.—The efficient power of a gas engine is not a matter dependent wholly, or even largely, on relative proportions among any of the working parts, and, at most, the figures given above are averages for the best obtainable conditions. Such favorable conditions consist very largely in such economy as may be obtained by keeping the jacket water at proper temperature—the higher temperatures at a few degrees below the boiling point seem best calculated to prevent over-absorption of heat units at every stage of the cycle—and to such as may be obtained by securing fuel mixtures and conditions favorable to rapid ignition. Bearing in mind these elements of variation in our estimates on power, we may readily understand that the efficiency of a gas engine is expressed by "the ratio of heat units turned into work, as compared with the total heat produced by combustion." By far the greater proportion of gas engines—those employed alike for general power purposes and in propelling motor vehicles—have water-cooled cylinders; the water for this purpose being admitted to a jacket or water space cast around the cylinder's circumference, and circulating between that space and the feed-tank or cistern, in accordance with the laws of liquids, which cause the heated layers to rise from the bottom to the top of the reservoir, and the cooler layers to fall correspondingly. As stated above, the foremost utility subserved by this arrangement is that the temperature of the cylinder is normally maintained below the point at which the lubricating oil will otherwise carbonize. Furthermore, the walls would also become so heated that the fuel charge would be fired out of time, with the result of disarranging the cycle and rendering the engine inefficient. That this result would follow is practically demonstrated in engines of the Hornsby-Akroyd type, wherein, instead of any spark, tube or other timed devices to fire the charge after the cylinder has fairly taken up its cycle, the heated walls of the combustion chamber provide the necessary temperature under cycular conditions. This combustion chamber is unjacketed and connected to the jacketed cylinder chamber by a passage of small diameter, so that only a minute portion of the contents of either will mix freely, except under compression. During the aspirating stroke of the piston the gas mixture is fed into this unjacketed chamber, and the air into the cylinder space, with the result that, no portion of its heat being absorbed by jacket water, the temperature is raised to the firing point of the fuel by the mixture of air under the added pressure of the compression stroke. This result generally follows after the firing of one charge by external means of raising the temperature, and is to be attributed most largely to the absence of the water-jacket. Thus, although the "cooling system" is a positive necessity in the space swept by the piston, for the reasons above stated, it forms a serious consideration in estimates on efficiency by absorbing a large proportion of the heat units generated by ignition of the fuel, and thus, under any conditions operating to reduce the total efficiency, even though by only a fractional ratio.

Jacket Water: Its Rate and Quantity.—On this point Hiscox makes an interesting statement on the proportions of absorbed and efficient heat units, as estimated under typical conditions. He says:

"In regard to the actual consumption of water per horse-power and the amount of heat carried off by it, the study of English trials of an Atkinson, a Crossley, and a Griffin engine showed 62 pounds of water per indicated horse-power per hour, with a rise in temperature of 50° F., or 3,100 heat units carried off in the water out of 12,027 theoretical heat units that were fed to the motor through the 19 cubic feet of gas at 633 heat units per cubic foot per hour.

"Theoretically, 2,564 heat units per hour is equal to one horse-power. Then, 0.257 of the total was given to the jacket water, 0.213 to the indicated power, and the balance, 53 per cent., went to the exhaust, radiation and the reheating of the previous charge in the clearance and in expanding the nitrogen of the air. * *

"In a trial with a Crossley engine, 42 pounds of water per horse-power per hour were passed through the cylinder jacket, with a rise in temperature of 128° F.—equal to 5,376 heat units to the water from 12,833 heat units fed to the engine through 20.5 cubic feet of gas at 626 heat units per cubic foot.

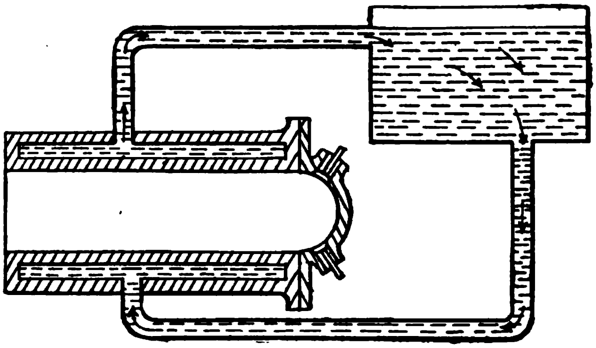


FIG. 143.—**Sectional View of the Water Jackets and Water Circulation Connections of a Gas Engine Cylinder, in which the circulation operates through gravity. The arrows indicate direction of circulation current.**

* * * * * * * * * *

"An experimental test of the performance of a gas engine below its maximum load has shown a large increase in the consumption of gas per actual horse-power, with a decrease of load, as the following figures from observed trials show: An actual 12 H. P. engine at full load used 15 cubic feet of gas per horse-power per hour; at 10 H. P., 15½ cubic feet; at 8 H. P., 16½ cubic feet; at 6 H. P., 18 cubic feet; at 4 H. P., 21 cubic feet; at 2 H. P., 30 cubic feet of gas per actual horse-power per hour. This indicates an economy gained in gauging the size of a gas engine to the actual power required, in consideration of the fact that the engine friction and gas consumption for ignition are constants for all or any power actually given out by the engine."

Gas Consumption and Power Efficiency.—Such facts bring us to an interesting situation in regard to estimating for the highest power-efficiency in a gas engine. As has already been stated, an increase in compression, involving a smaller combustion chamber or a longer stroke, ensures a higher temperature and explosive force at ignition. But, in obtaining these ends by such relatively longer piston-sweep, we are met by the difficulty incident upon exposing the ignited gas to a commensurately larger area of heat-absorption through the circulating jacket-water. As it is impracticable to leave any portion of the sweep space unjacketed, it is obvious that economy in this respect must be obtained by some mechanical or physical variation in the conditions. Thus, for example, considerable economy in fuel-consumption may be obtained by increasing the speed of the engine, which, when the cycle is well established, involves that the explosive impulses succeed one another so rapidly that the percentage of heat units absorbed by the jacket water is constantly reduced. This fact is shown by the data above quoted for a 12 H. P. engine, driven successively at 10, 8, 6, 4 and 2 H. P. and showing an increase in gas-consumption per horse-power in inverse ratio to the effective power-output. Such a reduction of power-output involves, of course, a lower speed, and is accomplished by regulating the gas and air supply. But if, according to the figures quoted above, a 12 H. P. engine at full power consumes 15 cubic feet of gas per horse-power per hour, which is 180 cubic feet per

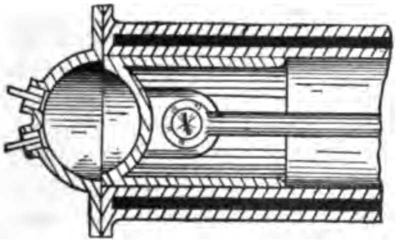


FIG. 144.—Section through a Gas Engine Cylinder having a spherical clearance and a spherical depression on the piston head. The shaded sections at top and bottom indicate the water jackets.

hour, it will at 10 horse-power consume 155 cubic feet, or 86 per cent.; at 8 horse-power, 132 cubic feet, or 75 per cent.; at 6 horse-power, 108 cubic feet, or 60 per cent.; at 4 horse-power, 84 cubic feet, or 46 per cent., and at 2 horse-power, 60 cubic feet, or 33 per cent. The waste in fuel gas under low speed and low power conditions may thus be readily understood—one-sixth of the stated horse-power from one-third of the full gas supply. It may thus be understood why that the speed of the engine, usually expressed as "revolutions per minute" of the fly-wheel, is an important item in all formulæ for calculating the horse-power. The gas engines built for automobile use are invariably of high speed-capacity, and also represent the highest point of economy.

Because of the fact that a reduction of the charge involves a nearly corresponding loss of power output in a gas engine, it is usually believed that the speed of the carriage can be varied only by the change-speed gear. On this point, however, Mr. C. E. Duryea says:

"In order to vary the speed of a carriage on a given road, it is necessary to vary the fuel supply, because if the lower gear is used, the engine, having less work, will race and the governor must then act, which is a method of varying the fuel supply. The speed-changing gear is provided in connection with gasoline engines, because such engines are not provided with variable cut-offs and are, therefore, not considered economical with various sized charges. On this account a motor of average size is used, and its deficiencies made up for by change of gearing. The Duryea practice is to provide a large motor, just as is done with a steam engine, and to throttle it over a wide range regardless of the loss of economy. As a matter of fact, this loss is more seeming than real, for, with the speed-changing mechanism, a constant mechanical loss is present which balances largely, if it does not exceed, the efficient loss of the motor by throttling. We are, therefore, able on good roads to drive our carriages at from three to thirty miles per hour by varying the speed of the motor by a throttle, and we use the gearing only for hills that are beyond the capacity of our motor as ordinarily geared."

Heat Economy: Spherical Clearance.—A number of gas engines achieve an economy in the use of heat and power units by having the piston and the combustion chamber of concave profile, so as to form a spherical, spheroidal or elliptical clearance at the end of the in-stroke. That is to say, the rear end of the cylinder is dome-shaped and unjacketed, and the opposing end of the trunk piston is correspondingly hollowed or concaved. The spheroidal clearance, formed when they are in contact or proximity, is, of course, deformed as the piston makes its out-stroke, but the end of economizing a considerable percentage of heat units is conserved by thus providing a large uncooled surface at either end of the combustion chamber during the entire cycle. Indeed, while this arrangement permits of a clearance, at the end of the in-stroke, of the smallest possible area on the cylinder walls, it provides a total increase in clearance volume on a stated wall surface between 20 and 40 per cent. in engines of ordinary design. Hiscox estimates that, while the wall surface of a cylindrical clearance space of one-half its unit diameter in length contains 3.1416 square units and 0.3927 cubic unit, the same surface in square unit measure, with a spherical combustion chamber has a volume of 0.5236 cubic unit, representing a gain in volume of 33 1-3 per cent. (5236—3927=1309×3= 3927). Such superior volume, on equal wall surface, being fully available at the moment of explosion, when the greatest possible degree of heat

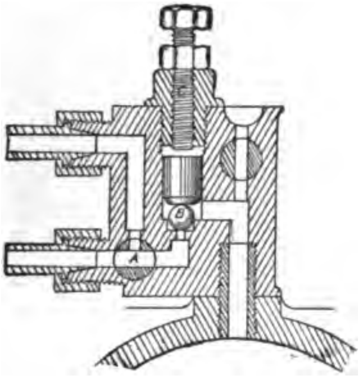


FIG. 145.—The "Lombard" Improved Cylinder Cooling Device. Instead of wing flanges, or jacket water, this system provides for cooling the cylinder by injection of a small quantity of water, atomized by suction of the piston. This water comes through the lower tube to the left of the cylinder head, passing through the three-way cock, A, and the ball valve, B. The lift of the ball valve is determined by the adjusting screw, C. When water is not required, the three-way cock is turned so as to return it to the tank through the upper left-hand tube. The theory is that superfluous heat will be absorbed in vaporizing the injected water.

and pressure is desirable to promote expansion, must vastly increase the effective power of the engine. Furthermore, although this arrangement is perfectly satisfactory in checking the absorption of heat units until the full force of the explosion has been realized, it is ineffective for producing a hot surface, firing temperature, such as is seen in the Hornsby-Akroyd engines, from the fact that the concave surfaces of cylinder end and piston head are open to a large heat-absorbing space, and hence quickly fall in temperature.

Heat Economy: Temperature of Water.—Another consideration of importance in calculating for heat economy in a gas engine is that the temperature of the jacket water should be maintained at a point favorable to moderate absorption of heat units. It is an error of somewhat common occurrence to suppose that the conditions of cycular operation demand that this temperature be as low as possible; the popular notion being that the cylinder requires some kind of *freezing* process in order to be properly "cooled." As we have already stated the real object of the cylinder cooling system, it is necessary only to add that the requirement is that the temperature should be kept somewhat below a definite high point, and that, as can be readily understood at this stage, the efficiency of the engine is decreased very nearly in proportion to the thermometric fall below that point. Thus if we play a jet of water from an ordinary garden hose upon a gas engine in operation, we will very quickly discover that its motion is effectually checked; whereas, if we supply the jacket system with water of slightly below 100°, Centigrade, we will

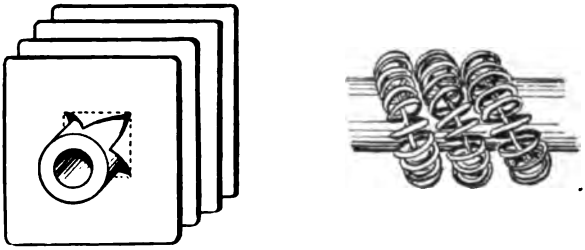


FIG. 146.—Details of Two Descriptions of Water Cooling Radiators. In the first, the pipe is surrounded by metal fins, let on as indicated; in the second, it is surrounded with coils of helical wire.

discover that the efficient power is increased in ratio with the rise in temperature. Thus, as is being advocated by some of the foremost authorities on the subject, the best practice is to supply water to the jacket at a temperature of a few degrees below the boiling point, permitting it to be returned to the reservoir at a temperature slightly above. Some hold that even higher temperatures are practicable.

A well-known manufacturer of gasoline carriage motors writes as follows: "A motor is hotter when the water is boiling rapidly than when it is boiling slowly, and the fact that more heat units are being absorbed by the water proves that the engine is doing harder work and not that it is cooler than before. The writer favors boiling water as the proper temperature and a gravity circulation as the proper circulating method, because this method most nearly insures a fixed temperature for the motor to work under. If kept below the boiling point the temperature of the motor will vary as the work varies. If air-cooled it will vary with the wind or the speed of the vehicle. If circulated by pump the temperature will vary as the speed of the pump varies, but with the boiling water system it remains reasonably constant and permits the finest adjustment of the mixture and the best results from the sparking." Other authorities seem to disagree with his position.

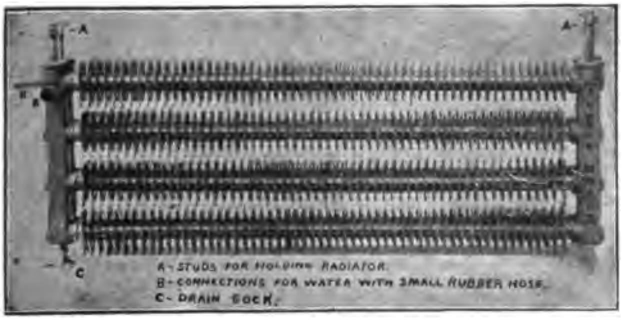


FIG. 147.—Fin Cooled Radiating Tubes used on the "Dyke" Carriages, with parts and connections indicated.

Heat Economy: Rate of Water Circulation.—In the excellent and suggestive treatise on "Gas and Oil Engines," given in

"Power Quarterly," for October, 1900, occurs the following significant passage:

"The more rapidly the water passes through the jacket, the lower will be the temperature of the issuing jacket water, but the heat units will be greater, within the usual limits of practice. For example, suppose the jacket water passes through at the rate of 16 pounds a minute and rises from 60° F. to 140° F. in passing through. To raise 16 pounds of water 80 degrees requires 1,280 B. T. U. (British thermal units), and as the difference between the average temperature within the cylinder (usually about 1,000° F.) and that of the jacket water (in this case 100°) is 900 degrees, there are 1,422 heat units per minute transmitted through the walls of the cylinder per degree of difference between inner and outer average temperatures.

Fig. 148.—"Crest" Double-Opposed Cylinder Gasoline Vehicle Engine, showing radiating ribs for cooling cylinders. The cylinders of this motor are in line, not off-set, as in some makes, the two cranks working on one crank pin. Owing to the method of joining the crank case on its diameter, all the working parts may be readily reached by unscrewing four bolts. Among the special features of this motor are the relief valve, which opens, hence interrupting operation as the wagon coasts down hill, and the automatic cut out for the battery circuit which operates when the engine is at a standstill.

"Now reduce the rate of flow of the jacket water to 9.57 pounds, and, assuming that the average temperature in the cylinder remains constant, the water will issue at a temperature of 190° F. This means a rise of 130 degrees, and to heat 9.57 pounds of water per minute 130 degrees, will require $9.57 \times 130 = 1,244$ heat units per minute, which is 36 less than before. A saving of 36 heat units per minute means

$$\frac{36 \times 778}{33,000} = .8487 \text{ H.P., gross.}$$

"As a matter of fact the flow of water would need to be less than 9½ pounds a minute in order to raise the temperature to 190° F., because as the jacket water increases in temperature, the average temperature in the cylinder increases, making the difference between the two less than if the internal temperature remained constant. This decreases the transmission of heat units to the water. The effect of varying the flow of jacket water cannot be computed accurately, because the internal temperature cannot be computed, and the exact heat conductivity of the cylinder walls is unknown. But, as the foregoing rough example clearly shows, the temperature of the issuing jacket water should be kept as high as practicable by adjusting the rate of flow.

"The limit to the allowable increase in jacket water temperature is set by the cylinder oil. The cylinder walls must not be allowed to become so hot as to decompose the oil, for the very obvious reason that decomposed oil does not lubricate. When the construction of an engine is such that the piston cannot be inspected there is no reliable way of determining the conditions of lubrication at high temperatures without endangering the cylinder wall and piston surface. But, as a rule, the jacket water can be run up to 200° F. without risk of decomposing the cylinder oil, if a first-class oil is used."

Such principles as have been mentioned thus far are competent in evidence for the statement that the operative conditions of the gas engine strike a balance between very definite extremes in several particulars, which, if not carefully noted, quickly reduce both the motion and the effective power-output. We have scarcely stated that the cylinder must be regularly cooled, when we are obliged to modify the assertion by saying that it must not be *too cool*, nor yet *too hot*, lest the very difficulties we aim to avoid occur with even greater danger. The same dilemma is met in the attempt to provide against the over-absorption of heat units by regulating the circulation rate of the jacket water: If the rules for ensuring economy are carried too far the good effects of the cooling are neutralized. Water in a paper bag may be boiled over a gas flame, because it absorbs heat faster than does the paper. In the same way, by the use of a water cooling system, a temperature very near to the melting point of steel (2560° F., 3021° absolute) may be reached at the explosion moment of the fuel gas in the cylinder, without destroying the engine or decomposing the lubricating oil, which carbonizes usually at a temperature of about 1,000°, Fahrenheit, more or less.

Jacket Water Circulation.—With the gas engines used for stationary power purposes, the jacket water may be drawn from and returned to a special tank or reservoir, thus ensuring sufficient circulation to regulate the temperature of the water fed to the jacket, but with many vehicle motors is used a supplementary radiating cooler, through which the ejected water passes on its way back to the tank. The most approved form of such a cooler, as used at present, consists in a coil or train of copper tubes, on which are sprung rows of fins, or flanges, of tin or aluminum. Another form has the same train of tubes spirally corrugated and wrapped about with lengths of wire rolled into very nearly the shape of a spiral spring. The spring, or flanges, just mentioned consist of a number of metal discs, in the centre of each of which an X-shaped cut is made. The points thus formed, being bent back, leave an orifice for introducing the tube, and when the discs are in place serve to keep them at proper distance. The fins afford a large heat-radiating surface for the water tubes, which is further increased by so lengthening and coiling the pipes as to expose the greatest possible surface to the air, under draught. The standard Daimler cooling device is a tank at the front of the bonnet pierced by a large number of tubes, like a fire tube boiler.

Circulating Pumps.—The circulating pump is most commonly used in the belief that it affords a ready means for regulating the rate and temperature of the jacket water supply, which could not always be the case with a mere gravity system. Such, however, is not precisely the case; since such pumps, being generally driven direct from the motor, operate at a speed varying with the motor speed. Thus, on starting the motor, it begins pumping cold water into the jacket, although no occasion exists. It pumps slowly at slow speeds, although the motor may be taking large charges and heating itself rapidly, as when ascending steep hills. It also pumps rapidly at high speeds, although the wind pressure and cooling effect may be very great, as on smooth roads. Could such circulation pumps be always used in connection with a thermostat, in order to operate to the even regulation of the motor temperature, the results would be much more favorable.

Solutions to Prevent Freezing.—In order to prevent freezing, the jacket water, when the engine is not in operation in cold weather, solutions are used, notably of glycerine and of calcium chloride ($Ca\ Cl^2$). The proportions for the former solution are equal parts of water and glycerine, by weight; for the latter, approximately, one-half gallon of water to eight pounds $Ca\ Cl^2$, or a saturated solution at 60°, Fahrenheit. This solution ($Ca\ Cl^2 + 6\ H^2\ O$) is then mixed with equal parts of water, gallon for gallon. Many persons complain that $Ca\ Cl^2$ corrodes the metal parts, but this warning need do no more than urge the automobilist to use only the chemically pure salt, carefully avoiding the "chloride of lime" ($Ca\ O\ Cl^2$).

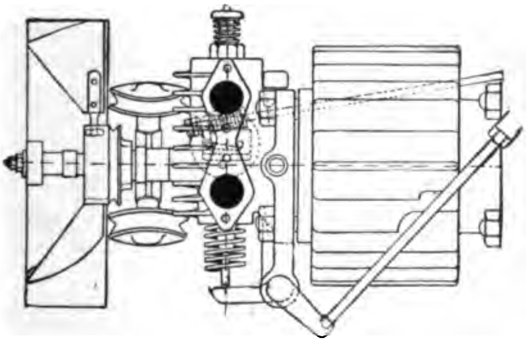


FIG. 149.—Detail Cylinder Head of the Simms Cycle Motor, showing fan wheel, cooling ribs, and peculiar arrangement for opening the exhaust. Similar fan wheels are used on several types of light vehicle motor.

Air Cooling for Cylinders.—While, as a general proposition, it may be said that the cooling of a gas-engine cylinder is best accomplished by water-circulation, a number of recent carriages both light and heavy have successfully used air-cooling devices. To within a very few years it has been held that air cooling is impracticable for vehicle motors, and, on the basis of trials made by French builders, the statement has always been made that, while an air-cooled cylinder will work very well on a light high speed vehicle or cycle, it is impossible for automobiles of large power, particularly in climbing hills and in hot weather. Daimler's early motors were air cooled by means of a rotary fan on the crankshaft that created a forced draught through an air jacket surrounding the cylinder, as is shown in a subsequent cut. Later on, automobile builders, such as Mors, Decauville, Darracq, and also Panhard-Levassor, used motors on heavy carriages with the cylinders cooled by peripheral fins or flanges. The principal trouble with these cylinders was that under heavy load the generating of heat was so rapid as to clog the piston, ignite the lubricating oil, or to produce premature explosion of the charge. Largely for this reason, the water-cooling system become universal, except for very light vehicles and cycles intended to be driven at high speeds. In order to assist the work of cooling the cylinder, several builders early adopted the plan of using rotary fans to create a forced draught against the fins cast on the cylinder's walls. Such a device greatly increased the cooling properties of the motor, even when the vehicle was moving at low speed. This was particularly true with the Simms fan-cooled cylinder, on the walls of which were cast very deep longitudinal flanges. An English builder, Turell, constructed a three-wheeled carriage propelled by a motor with ribs of this description. It was found however that, with a motor of 2 horse-power, and over, the draught created at high speed was not sufficient for cooling and that the cylinder would quickly become overheated, with the result the exhaust walls would be loosened and the head frequently red hot. It seems to have been reserved for American inventors to design

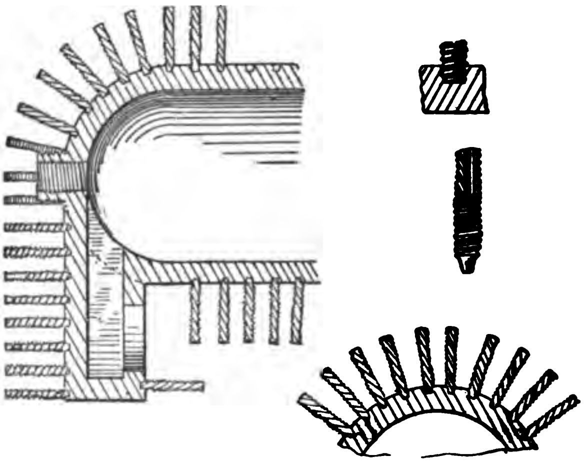


FIG. 150.—The "Knox" Pin-Cooled Cylinder. In this engine, pins are used for radiating instead of the usual flanges or ribs as on other air-cooled cylinders.

successfully air-cooling systems. One of the most noteworthy of this is the Knox pin-cooled cylinder, in which a large number of brass pins are screwed into suitable holes on the outside of the cylinder's wall. According to claims this device increases the cooling surface nearly 100 per cent., and is exceedingly efficient in utilizing the heat absorbing properties of air under draft. In connection with the use of corrugated pins on the outside surface of the cylinder, a rotary fan is used, and this, being driven direct from the main shaft by a worm gear, always rotates with the speed of the engine, thus providing a sufficient draught for cooling purposes at all speeds. The problem has been differently solved by other American inventors. Thus the builders of the Crest carriage use a cylinder with deep longitudinal flanges, which according to claims and reported tests is very efficient in spite of the fact that the motor is set vertically in the carriage. Briefly described, the flanges are so arranged as to be deepest over the combustion spaces, thus giving the cylinder an approximate pear shape. The success of the air cooling is due to the extremely large radiating surface, due to the use of very wide vertical

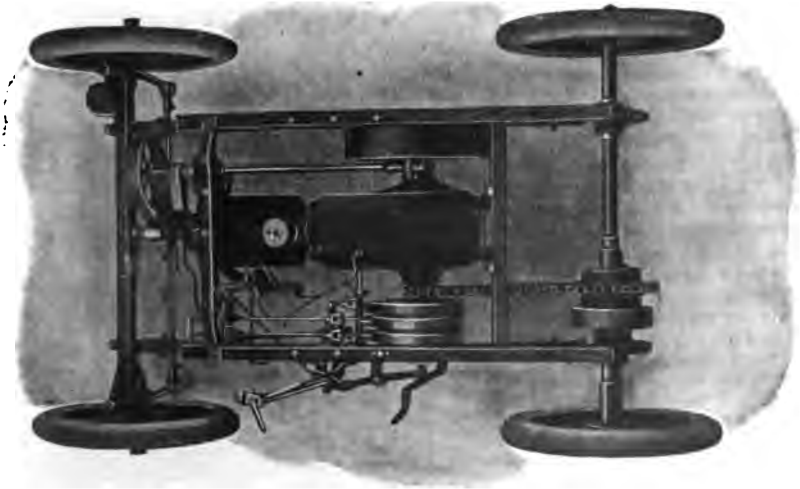


FIG. 151.—Knox Single-cylinder Four-wheeled Car, showing pin-cooled cylinder and great length of motor.

radiating vanes, to the free passage of air directly behind the valve chamber—this space being usually filled with solid metal—and to the slight tapering of the upper end of the piston. The motor is of the conventional vertical type, excepting that the inlet and exhaust valves are larger in proportion to bore than is usually used. According to claims, apparently verified by independent test, it can safely run at a speed of between 1,900 and 2,000 revolutions per minute.

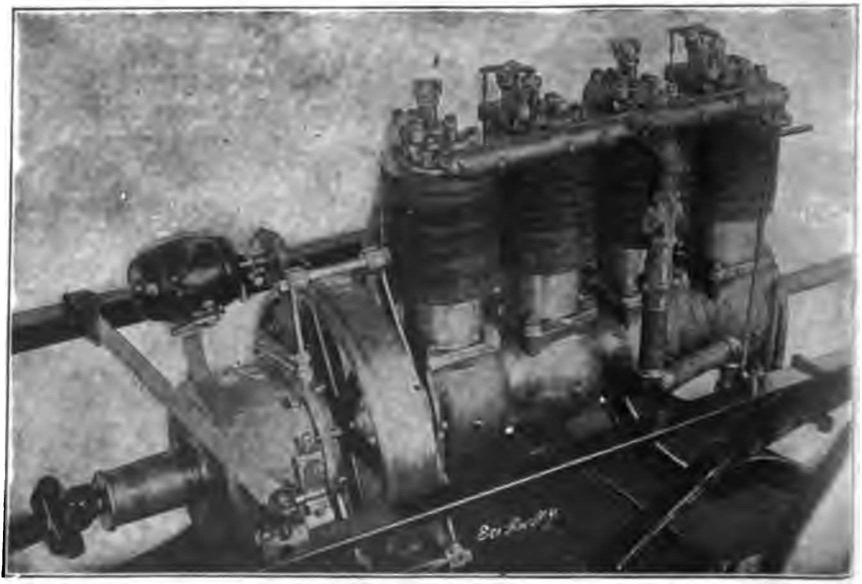


FIG. 152.—Franklin Four-cylinder 24-horse-power Engine, showing great number of flanges for cooling the cylinders.

The Franklin system of air cooling is different from either of the foregoing although equally efficient in operation. The plan is to use a four-cylinder motor of small bore and short stroke, 3½ x 3½ being the dimensions for the cylinders of a 12-horse-power engine. Combined with this is slow speed; two together enabling superfluous heat to be rapidly absorbed as the car travels. The flanges of the cylinder are very numerous, although not of great depth.

The most recent device for air-cooling of cylinders is that used on the Regas engine, upon the outside walls of which is placed a sheet steel jacket carrying 172 copper tubes of ½ inch diameter and 1½ inches long Each of them has longitudinal slots near its base. As heat is generated in the operation of the motor, a circulation of air is set up, the hot air being given out at the ends of the tubes, on the principle of the Bunsen burner. In this manner, there is a constant supply of cool air for absorbing the heat of the cylinder and the circulation is maintained apart from the use of a fan or other mechanical contrivance. According to claims, a 4½x5 double inclined cylinder motor, developing 12 horse-power at 1,200 revolutions, can be perfectly cooled by the use of 172 of such Bunsen tubes in each cylinder.

FIG. 153.—Cylinder of the Regas Motor, showing Bunsen tubes let into steel jacket.

A cylinder with such a Bunsen tube cooler can be perfectly operated on a stationary engine running at 1,000 revolutions per minute.

CHAPTER SEVENTEEN.

ON FUEL MIXTURES AND THE CONDITIONS RESULTING FROM COMBUSTION OF THE CHARGE.

Causes of Imperfect Combustion.—In addition to the general conditions of gas engine efficiency thus far given, it is important to consider the cause and consequences of imperfect combustion, which, as may be readily understood, is a fertile source of irregular action and loss of power. In the first place, it is important to consider the matter of proper proportions of air and gas in the fuel mixture, since too much or too little of either element results in weak explosion. Practically, this is a question of proper carburization, and may be determined by experience quite as efficiently as by calculations. In the second place, sufficient compression of the fuel gas should be provided for, in order that, despite the presence of the exhausted products of previous combustion, there may be an adequate mixture of the charge, giving a fair degree of uniformity throughout. The result of an uniform mixture is to provide one condition of rapid firing, since the gradual and partial combustion, so frequently a source of annoyance and lost efficiency in gas engines, comes directly from imperfect mixture under compression. This brings us to the third point—what method of firing is the most efficient in securing the quickest possible combustion? The first point involves several important considerations, which we will now proceed to touch briefly; the second is largely a matter of structural proportions, after the question of proper mixture has been determined, as is indicated by much already said; the third will be fully discussed under the head of firing devices.

The Theory of Fuel Mixtures.—The object of mixing atmospheric air with the fuel gas is to obtain a sufficient amount of oxygen to enable combustion to take place. All oils and spirits may be ignited and burned at the proper temperature, differing for each particular substance, if that temperature be produced where air can circulate freely. At certain definite temperatures such liquids give off inflammable vapors, and at a somewhat higher point may be ignited and burned themselves. The first point is called the ***flash point;*** the second, the ***fire point.*** However, when shut off from air supply, neither the vapor, so formed, nor the liquid itself may be ignited. This is the reason why that oil vapor may be fed into the superheated combustion chamber of the Hornsby-Akroyd engine, as already described, and fail to explode until, by the completion of the compression stroke, a sufficient quantity of atmospheric air has been mixed with it.

In order to illustrate, the following list of several familiar hydrocarbons, together with their flash and fire points, is quoted from a well-known authority:

	Flash Point.	Fire Point.
Commercial brandy	69	92
" whiskey	72	96
" gin	72	101
Kerosene (average quality)	73	104
Petroleum (high test)	110-120	140-160

Proportions of Fuel Mixtures.—In the free air the only point to be considered is the required temperature for flashing or firing, since atmospheric circulation will always supply the full amount of oxygen for combustion. In a gas engine cylinder, closed from the outer air, it is necessary to know how much air must be admitted. The most efficient proportions of air and gas, mixed to give a perfect combustion in a closed cylinder may be considered a matter in many respects relative to the kind of gas employed—some gases require more, some less, for the best effects from combustion. In general, however, the data on coal gas may be taken as typical for most fuels available in ordinary gas-engine service. With this fuel the figures for efficiency range between 6 to 1 and 11 to 1 for air and gas, respectively. That is to say, with a mixture of about 5 to 1 or of about 12 to 1, for example, the effective pressure due to combustion—if combustion is possible at all—shows a marked falling off, which continues thereafter as the proportion of air in the mixture is diminished or increased. Between the efficient extremes, however, it has been found that, although the actual indicated explosion pressure decreases in ratio with the increased percentage of air in the mixture, the efficiency steadily increases until the point of 11 to 1 is approximated. This fact is explained by as-

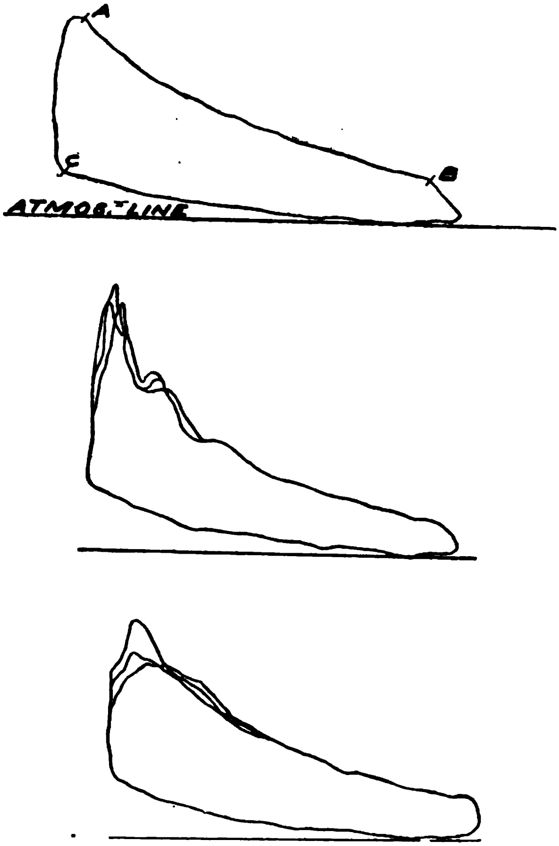


FIG. 154.—Gas Engine Indicator Cards. The first diagram is an average good card, showing, however, some slight fluctuations in the lines. The explosion line is from C to A; the expansion, from A to B; the exhaust at B. The suction stroke generally approximates the atmospheric line, from which the curve of compression rises to C. The second diagram is from an engine running under half load; the third from one at full load. Both exhibit the variations in the expansion curve, usually attributed to consecutive explosions. The second and third cards are composites of three successive strokes each.

suming that, in increasing the proportion of air in the mixture, the temperature per unit of gas is raised, although the temperature per unit of the mixture of gas and air is lowered. Since, therefore, the gas itself is the sole agent of efficiency—the condition necessary to explosion being all that is furnished by the admixture of air—the increase in the proportion of air in the charge, up to the specified limit, increases the total efficiency, even though lowering the pressure of the explosion.

Some Results of Imperfect Compression.—On account of another consideration, the proper proportion of air and gas for a given case is important, and, when combined with an adequately adjusted compression, is a factor in promoting efficiency. This refers to the fact that, as shown by numerous indicator diagrams, the firing of the whole mass of gas, contained in cylinder, is not always an instantaneous process—some diagrams showing several consecutive explosions, of decreasing effect to be sure, which tend to make the action of the engine fluctuating and uncertain. This effect has been ascribed to a "defective mixture," but such could not be the sole cause of all the phenomena, since alone, it would rather occasion an explosion of insufficient pressure, if any explosion at all. The truth is that the mixture, in such cases, is defective from the fact that it does not contain sufficient oxygen to the total bulk to produce perfect ignition, in view of the presence of burned out gases in the clearance. As described by some writers on the subject, these residua of previous combustions develop the tendency to *stratify* the mixture, and, unless the air is in proper preponderence to the percentage of pure fuel gas, or, unless the compression ratio is adjusted to produce adequate blending of the inflammable elements, the result will be several explosions, as the successive layers of gas, separated by unburnable products, become ignited. Among other elements that combine to promote the conditions just specified are certain chemical changes, giving rise to gases of high fire temperatures, or causing shrinkage in the proportion of good fuel mixture in the cylinder. Defective or inferior firing devices are also liable to produce slow and irregular combustion.

As many of the conditions of gas engine operation seem to be somewhat uncertain, in the minds of even prominent authorities, it is only fair that we quote several opinions contrary to those already stated. A well-known designer and manufacturer of vehicle motors, in a letter to the author, denies the theory of "stratification" of the charge with the residua of previous combustions, asserting that the indicator diagram phenomena, usually attributed to several successive explosions, are due rather "to irregularities of the indicator or to vibrations of the gas in the indicator piping, and not to variations in the rate of combustion." He also deprecates the importance given by some writers to the efficiency of a high compression in producing a better blending of the fuel mixture, attributing the good results, apparently thus obtained, to the time occupied in making the compression, which also serves to perfect the mixture, and also to the fact that compression produces heat, thus also promoting readiness of ignition.

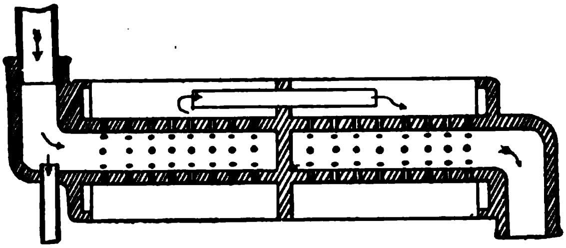


FIG. 155.—The Benz Exhaust Muffler. The arrows indicate the course of the expanding exhaust products. Entering at the left, they pass through the perforations in the tube; thence through the smaller tube in the larger chamber; again through the perforations in the right-hand section of the tube, and to atmosphere. The breaking-up of the gas in expansion silences the noise of its exhaust to atmosphere.

Defective Combustion: Advantages of Scavenging.—In addition to the irregularities of action, just enumerated, the presence of burned out gases in the clearance operates effectually to reduce both the pressure and temperature of combustion by several per cent. This fact is demonstrated by comparing the figures for explosion pressures and temperatures of scavenging and non-scavenging gas engines of the same proportions. For although, as we have already seen, the figures for compression pressure and temperature are higher for non-scavenging, or ordinary, gas engines than for the other variety, due, as has been asserted, to the recompression of burned products in the one engine, or else to the use of cooling air currents to expel these in the other, the case is directly reversed at the moment of explosion. From this fact, as may be readily understood, a scavenging engine should be the more effective, as securing the better ignition of the charge and as permitting the loss of less heat in proportion to the total of units generated. The principle has been adopted successfully with several well-known types of stationary gas engine, although, so far as the writer can ascertain, few, if any, attempts have been made to adapt it to use in motor vehicles.

Its inefficiency in this connection would arise from several conditions, prominent among which would be the added complication necessary to the end of eliminating the burned gases under high speed conditions and the uncertainty involved, with the constantly recurring danger of thus lowering, rather than raising, the value of the charge by irregular variation of the mixture. Also the rate of jacket water consumption would always be greater owing to higher temperatures. The force of these remarks may be understood when we consider that the most usual and practical method of scavenging a gas engine cylinder is to drive out the burned residua by admitting a current of fresh air into the clearance. The method of extending the sweep of the piston clear to the rear end of the combustion chamber, so as to expel the contents mechanically, was used with success on the Atkinson variable stroke gas engine, now no longer manufactured, also on the Diesel engine, but it is the least economical procedure, owing principally to the necessity of using a plane surface cylinder head instead of one of segmental profile, and some such complicated mechanical devices, as were used in the Atkinson cycle. The fresh air method requires only that the crank case be used as a pump chamber for the air.

Data on Scavenging Cylinder.—In order to show how that the burned out gases in the clearance operate to lower the explosion efficiency, we can do no better than quote again from the "Power Quarterly" treatise already mentioned. Here the following occurs: "The difference due to the presence of burned gases is considerable. A mixture of 9 to 1, with no burned gases present, gives a rise of about 2,373 degrees; the same mixture, compressed with the burned gases of a previous explosion in a clearance of 41 2-3 per cent. of the cylinder volume gives a rise of only about 1,843 degrees.

"The resulting temperatures of explosion in the two cases do not differ so greatly as the rise in temperature, because the scavenging engine starts from a lower initial temperature and the rise during compression is not so great. For example, assume an engine with 3.4 compression ratio, running scavenging with an initial pressure of 13.2 pounds and an initial temperature of 580°; and suppose a similar engine running plain, with 13.2 pounds initial pressure and 600° initial temperature. The results are compared below on the basis of a 9 to 1 mixture:

	Ordinary.	Scavenging.
Initial temperature	600	580
Compression temperature	921	858
Rise in temperature by explosion	1,843	2,373
Temperature of explosion	2,764	3,231

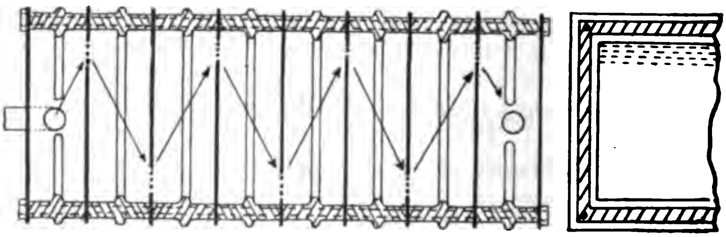


FIG. 156.—Section and End View of an Efficient American Muffler. The muffler consists of a series of chambers formed by screens, perforated alternately at top and base, so that the expanding exhaust gas follows the course indicated by the arrows; their passage through the perforated sections serving to break it up and silence the noise due to its pressure.

"In this comparison the difference in the rise of temperature is nearly 29 per cent., while the difference between the explosion temperatures of the two engines is only scant 17 per cent. A better comparison may be had by considering the pressures; these figure out as follows:

	Ordinary.	Scavenging.
Initial pressure	13.2	13.2
Compression pressure	68.86	66.4
Explosion pressure	206.65	250.0

"Thus, the scavenging engine shows a maximum temperature about 17 per cent. higher than the other engine, while its maximum pressure is a trifle over 21 per cent. greater. . . . . . While excessive explosion pressures are not desirable, it is clearly advantageous, within practical limits, to increase the difference between the maximum forward pressure and that of compression, because it increases the area of the indicator diagram. And as this result is obtained by scavenging, without consuming any more gas, the superiority of a scavenging engine is obvious."

Exhaust Losses in Heat and Power.—Having followed the operation of a gas engine through its entire cycle, discussing the several conditions of efficiency and the causes of lost power, it is proper to touch briefly on another notable cause of waste, which is frequently mentioned in gas engine treatises. This refers to the expulsion of a considerable proportion of heat and power units through the exhaust. According to average experience, there seems to be no practical method of utilizing any of the elements thus thrown to waste, unless we resort to contrivances for "compounding" the cylinders, somewhat after the plan of the double and triple expansion steam engines. The principal reason why this loss may not be avoided is that, as the gas, after explosion may not be expanded so as to stand at atmospheric pressure on the completion of the power stroke—the expansion line then standing generally about or above the figure indicated for compression pressure—it is necessary to open the exhaust before the completion of the stroke. This opening point is generally about $\frac{7}{8}$ stroke. Were the engine otherwise geared, and the piston allowed to receive the pressure of the expanding gas through its full stroke, the gas retained until that time would not exhaust fast enough to avoid buffing the piston on its return sweep, since through an appreciable distance the continued expansion would balance the rate of escape through the exhaust valve,

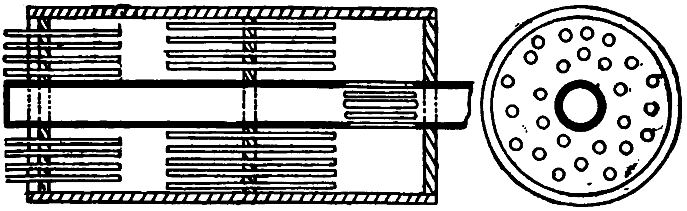


FIG. 157.—The "Loomis" Muffler. The exhaust enters the central tube at the right-hand end, passing out through slits shown in its side to the main chamber, where it is passed through a number of lengths of tubing. Leaving these it emerges to atmosphere through another set of tube lengths.

The effect of this would be to check the speed and power of the engine, with the result of absorbing about as much power as would on the other plan be turned to waste.

The Variation of the Curve of Expansion.—The reason given for the variation from the compression line of the curve of expansion following explosion is that the combustion is not only not instantaneous, but continues during the greater portion of the stroke, thus constantly keeping up the temperature and pressure, which would, otherwise, tend to fall regularly from maximum to atmosphere. Thus the expansion line does not meet the compression line at the end point of the stroke, as should be the case under theoretically perfect conditions, with the result that the exhaust valve must be opened before the completion of the stroke, as above stated. An interesting approximation of this standard is found in the Atkinson cycle scavenging engine, which, on account of certain mechanical peculiarities of construction, is able to expand the charge from 185 pounds at explosion to 10 pounds, gauge, at the completion of the power stroke. In this machine the piston rod is connected to a double toggle joint, as indicated in the accompanying diagram, with the result that the piston makes its four strokes in a single revolution of the fly-

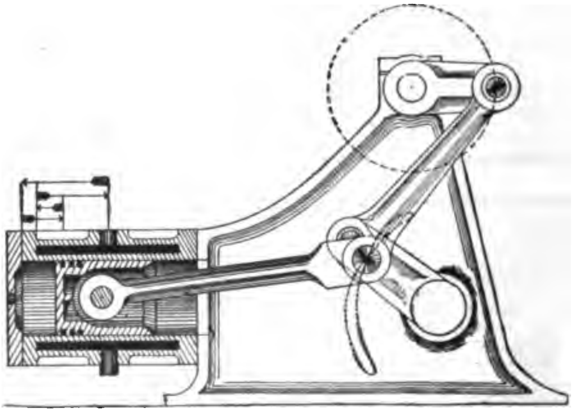


FIG. 158.—Section of the Atkinson Cycle Gas Engine, showing the varying lengths of the strokes—from the top, exhaust, expansion, compression, suction; also, the figure-of-8 path described by the toggle-jointed crank connections, and the path of the crank.

wheel, giving a suction stroke through about one-half the sweep length, a return compression stroke to a point about 5-6 the sweep, an impulse stroke from that point clear forward, and an exhausting stroke from end to end of the cylinder. As claimed in a published description, the working effects are that: "The clearance space beyond the terminal exhaust position of the piston is so small that, practically, the products of combustion are entirely swept out of the cylinder during the exhaust stroke, so that each incoming charge has the full explosive strength due to the mixture used.

"It is also possible to expand the exploded charge to such a volume that the terminal pressure will be reduced to the lowest possible point, and that, owing to the purity of the charge, the greatest possible pressure will be attained at the commencement of the expansion."

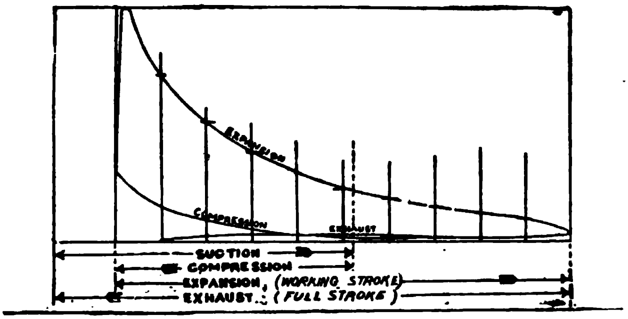


FIG. 159.—Indicator Card for the Atkinson Variable Stroke Four-Part "Two-Cycle" Gas Engine.

The accompanying indicator card of an Atkinson engine, of 18 I. H. P., working at 130 revolutions per minute, with a mean pressure of 49 pounds, shows the excellent results achieved by thus varying the length of the several strokes. But such a procedure is impossible in the ordinary four-cycle engine, which finds the only available method of securing approximately complete combustion in varying the proportions of the fuel mixture, and by scavenging the cylinder.

The Ratio of Expansion.—As may be readily understood, the practice of opening the exhaust valve at about ⅞ power stroke gives one reason why that the expansion ratio differs so greatly from the compression ratio, with which, theoretically, it should be identical. On the Atkinson cycle this correspondence is practically realized, but with engines constructed on the Otto cycle it represents the quotient found by dividing the sum of the total cylinder content (clearance plus piston sweep) and that portion of the stroke and clearance content, left behind the piston at the moment the exhaust opens, by the cubic content of the clearance. This may be expressed by the following formula:

$$Er = \frac{C + \frac{n}{C}}{B} = \frac{\text{Volume of Expansion}}{\text{Volume of Clearance}}$$

in which Er is the ratio of expansion.
C " the total cylinder content.
B " the combustion chamber or clearance content.
n " the numerator expressing the portion of the cylinder content left behind the piston at the opening of the exhaust.

Data on Losses by the Exhaust.—In the process of exhausting, the burned gases issue from the cylinder; first place, largely under their own force of expansion, which continues down to atmospheric pressure; secondly, after the change of stroke, under the force of the returning piston. The pressures and temperatures thus voided are, of course, in proportion, first place, to the figures realized in explosion, and, secondly, to the expansion ratio of the particular cylinder under test. Both are found to decrease with increasing ratios. Thus, under ordinary conditions with engines driven by illuminating gas, an explosion temperature of 3,000 and an explosion pressure of 250 for a ratio of 3 give an exhaust temperature of 2,158 and an exhaust pressure of 59.9; for a ratio of 3.5 they give 2,060 and 49.0; for a ratio of 4 they give 1,979 and 41.2; for a ratio of 5 they give 1,851 and 30.8; for a ratio of 6 they give 1,752 and 24.3.

In order to fully describe the situations involved, we can do no better than to quote again from the treatise already referred to in several connections. Here we have it that:

"The compression ratio ranges in present practice from 3 to 4; with the former ratio the exhaust pressure is never less than 35.7 pounds, and with the latter 24.7 pounds, absolute, and it is usually around 45 pounds for one and 30 for the other, as the explosion pressure is generally 180 to 200. So that there is a waste usually of 15 to 30 pounds available pressure at the end of the power stroke. And, as the explosion temperature is almost always around 2,500 and is frequently near 3,000, the temperature of the exhaust is generally from 1,600 to 1,900—say 1,760, average, or 1,300° by thermometer scale. This means that if the outdoor temperature is 70°, a difference of 1,230° is thrown away. And as the specific heat of the products of combustion averages .26, every pound of exhaust gas emitted at 1,300° F. into an atmosphere of 70° means throwing away $1,230 \times .26 = 319.8$ heat units, or $319.8 \times 778 = 248,804$ foot pounds of energy. . . . . . .

"Suppose we assume an expansion ratio of 5.8, in order to get a great expansion, and a compression ratio of 6. Then assume an ordinary engine, because the effect of explosion is not so great and a mixture of 12 volumes of air to 1 of gas, because that is the weakest reliable mixture. Starting with the highest practical initial temperature, 660°, and the lowest practical initial pressure, 13, the following results are obtained:

	Pressure.	Temperature.
Initial	13	660
Compression	146	1,236
Rise	——	1,755
Explosion	353	2,991
Exhaust	35.9	1,765

On Compounding Gas Engine Cylinders.—The enormous waste, as indicated by the figures given above, which show that over 7.5 horse-power per pound of fuel gas goes through the exhaust valves, is a good argument for seeking some device to utilize at least a part of this lost energy. The Atkinson cycle engine, as described above, seems to fill many of the requirements in this respect for stationary engines, but for motor carriage purposes compounding seems to be the most available system at present under consideration. The subject has been discussed at considerable length in magazines devoted to motor carriage interests, and an engine embodying the proposed requirements has been constructed by Messrs. Crossley and Atkinson in England. This motor, shown in an accompanying illustration, consists briefly of three cylinders—two primary, or high pressure, between which is a secondary, or low pressure, cylinder. The volume of the low pressure cylinder is about twice that of either of the high pressure cylinders, thus allowing the exhaust gas to expand very nearly to asmospheric pressure, when fed into it from either of the others. The crank shaft is so arranged that, while the two low pressure pistons are at the dead end of the in-stroke—the one, of compression, the other, of exhaust, for example—the low pressure piston is at the dead end of its out-stroke, or power-stroke. Thus the exhaust gas is fed to the low pressure cylinder from both high pressure cylinders alternately, and it performs a power-stroke once in each revolution of the flywheel, always alternately to either of the others. As may be seen from examination of the drawing, connection between the high pressure and low pressure cylinders is had by means of a triple piston valve moved longitudinally on a secondary shaft and so arranged that pure atmospheric air may be admitted to the centre cylinder, when either of the others misses fire. Compound

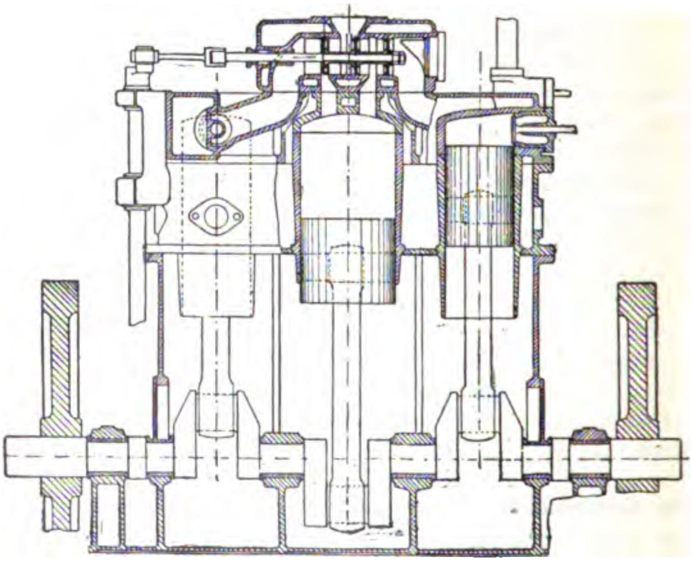


FIG. 160.—Crossley Three-Cylinder Compound Gas Engine. The two end cylinders are high pressure; the central one, low pressure. The exhaust from the two high-pressure cylinders is admitted, alternately, to the low-pressure cylinder by the piston valve, operated by the crank and rotating shaft shown at the left. The exhaust from the low-pressure cylinder passes upward through the port at its top.

gas engines, made by other engineers, have the cranks geared at a little over one-third of the total revolution, instead of at 180°, as in the one shown. It has also been proposed to make the volume of the low pressure cylinder at least three times that of either of the others, but this seems excessive from the fact that the expanding gas fed into it would expand to a point below atmosphere. The editor of the "Horseless Age" gives a formula demonstrating this, as follows:

$$P^1 = P \left(\frac{V}{V^1}\right)^y$$

in which P is the initial low-pressure pressure, V, the initial low-pressure volume, P^1, the final pressure, at the end of the low-pressure power-stroke, V^1, the final volume at the same point, and y, the ratio of the specific heat of the gas at constant pressure to the specific heat at constant volume, which is about 1.5 for gasoline exhaust. Then, taking as the value of P the average of 55 pounds, absolute, with 1-3 as the value of the fraction because the ratio of the cylinders is 1 to 3, we have

$$P^1 = 55 \left(\frac{1}{3}\right)^{1.5} = 10.6 \text{ absolute.}$$

The result shows a pressure of about four pounds below atmosphere, which, although indicating a very complete utilization of exhaust gas, involves a cut-off of the efficient power before the completion of the stroke, unless a compound gas engine be operated with some kind of vacuum-producing condenser, such as is so important an item with triple and quadruple expansion steam engines. How such an adjunct to a gas engine would operate, and what would be its construction, we need not pause to inquire here.

The Advantages from Compounding.—In addition to economy in heat efficiency, which is the primary object of compounding a gas engine, two other important ends are achieved. In the first place, the muffler, or exhaust silencer, may be dispensed with; since, as in the compound steam engine the highly expanded exhaust products issue to the air without noise. This is a decided advantage; for, since the principle of a muffler involves imposing obstacles, so as to break up the full force of the gas as it expands, it furnishes an undesirable back pressure that absorbs a goodly part of the output power. In accompanying diagrams several types of efficient muffler have been shown, but as the question of proportions is in place here a few facts will be given. As indicated by Roberts, the formula for the cubic content of a muffler best calculated to save power gives 3.5 times the square of the cylinder diameter in inches multiplied by the length of the piston stroke in inches, or

$$M = 3.5 D^2 L.$$

A French authority states that an engine of 8 I. H. P., running without muffler, gave 6.1 B. H. P. at 967 revolutions per minute, but, with muffler, gave the same efficiency only on 1,012 revolutions. He also found for a 2.25 I. H. P. engine an efficient output of 2.16 at 2,015 revolutions without muffler, and, of 1.91 at 2,057 revolutions with muffler, claiming a loss of 20 kilogrammeters, or 145 foot pounds per second.

In the second place, a compound gas engine of the Crossley-Atkinson type presents the advantage of affording a steady drive, as in a steam engine, thus obviating the necessity of leaving the fly-wheel to "store up" power sufficient for three idle strokes. It is probable that, as motor carriage construction approaches greater perfection, the subject of compounding will come increasingly to the front on account of these and other advantages.

CHAPTER EIGHTEEN.

GAS ENGINE EFFICIENCY, AND ITS OPERATIVE CONDITIONS.

Conditions of Operation: Maximum Efficiency.—Having now set forth and discussed several of the more important occasions of lost efficiency in gas engines, together with some of the methods employed to neutralize waste, it is proper to consider briefly the conditions of efficiency and their computation. As may be readily understood from the facts stated, no gas engine can realize the full power, which, theoretically, it should produce. Even under the most favorable conditions, with the observance of all rules and the use of all means, mechanical and otherwise, to conserve energy, it must fall below the figures reached by calculation. Thus, as given by several writers on gas engines, there are at least four different equivalents of the word, efficiency: Maximum theoretical efficiency, actual heat efficiency, mean efficiency and mechanical efficiency.

The *maximum theoretical efficiency* assumes perfect conditions and a perfect indicator card diagram, showing an output of power equal to the figures realized by the highest explosion pressure, with instantaneous and complete combustion and effective adiabatic expansion to atmosphere during the power-stroke. It is estimated, therefore, as the difference between the explosion temperature, absolute, and the initial temperature, absolute—which is to say the number of degrees rise from initial to explosion—divided by the explosion pressure. Thus it may be expressed as

$$\frac{\text{Rise in degrees}}{\text{Explosion temperature}} = \frac{T^{II} - T^{I}}{T^{II}} = \text{Efficiency.}$$

This formula holds good because, on the theory of the perfect gas engine, the gas, after explosion, should be expanded to atmosphere, with the utilization of every unit of heat, or the return to the initial temperature. The efficient figure, therefore, is the rise from initial to explosion.

Thus, assuming an initial temperature of 660°, absolute, and an explosion temperature of 3,000°, absolute, we have, by the formula,

$$\frac{2340}{3000} = .78$$

as the percentage of theoretical efficiency under such high temperatures.

Another formula calculates the maximum theoretical efficiency as the quotient of the initial temperature and the rise in degrees absolute to the explosion point. Thus:

$$\frac{660}{2340} = .282 \text{ and } 1-.282 = .718 \text{ per cent.}$$

In either case, however, the figures would be modified by the fact that the specific heat of all gases differs between the conditions of constant volume and constant pressure. Thus the specific heat at constant volume for a 12 to 1 mixture of air and coal gas is .1803, and for constant pressure, .2526. Their ratio is

$$\frac{.2526}{.1803} = 1.4$$

Consequently, to obtain the most exact figures, we must multiply the former quotient by 1.4 and subtract from 1, as before, to discover the percentage. Thus, we have the formula:

$$1 - 1.4\,\frac{660}{2340} = 1 - (1.4 \times .282 = .3948) = .6052$$

as the percentage.

The Actual Heat Efficiency.—Owing to various causes, partly mechanical, partly physical, as already discussed, even this percentage is impossible in an ordinary four-cycle engine; since contrary to the theory of the above formula, the exploded gas is not expanded to initial pressure and temperature, but only to a much higher point at exhaust. Instead, therefore, of the above formula, we divide the exhaust temperature, Fahrenheit, by the figure for internal temperature rise, Fahrenheit, multiply by 1.4 and substract product from unity. Thus, taking 1,500 as a fair average temperature at exhaust, we have:

$$1 - 1.4\,\frac{1500 - 461}{2340 - 461} = 1 - (1.4\,\frac{1039}{1879} \text{ or } .552 = .7728) = .227$$

as the percentage of efficient power to be realized from an average gas engine under most favorable conditions. The maximum theoretical efficiency, therefore, is impossible in practice, even under ideal conditions; since it assumes that the expansion line of the indicator diagram is perfectly *adiabatic*, which is to say, indicating an expansion without loss or gain of heat units, to atmosphere. The figures are valuable, most largely, as indicating the necessary limitations of gas engine operation and construction. Some of the best gas engines, however, give an indicated power-output of 30 per cent. and over, according to claims —some assert slightly higher figures—but, even with this low average the gas engine is superior to the steam engine.

FIG. 161.—The Duryea Three-Cylinder Gasoline Vehicle **Engine**, with half the **crank** case **sheathing removed**, showing **cranks**, crank shaft, cam shaft, and working parts. **The three cylinders have common supply and exhaust tubes**; the charge is controlled **by a single throttling link, shown at the** top, and the igniting circuit has three bridges **for the three cylinders**

Testing by the Pyrometer.—The formulæ just given illustrate one very essential point in gas-engine operation, which is that, given the temperature, absolute, at the moment of exhaust, the efficiency of the working cycle may be approximately estimated; always, of course, allowing due value to the heat losses through the cylinder walls, and otherwise, as above discussed. The heat of exhaust averages between 1,500° and 1,900°, absolute, according to the compression ratio, which determines the range of temperature rise at explosion; according to the expansion ratio, which determines the range of effective heat and power, and, consequently, according to the temperature of explosion. Of course, such high temperatures may not be determined by an ordinary thermometer; for, since the vaporizing point of mercury is at 675° Fahrenheit, no rise beyond that could be adequately measured. Accordingly, the device used is that known as a pyrometer, one form of which consists of an electric circuit containing a source of current, a galvanometer and an iron tube, enclosing a contact of an electrode of platinum and an electrode of iridium. When it is desired to determine the temperature of a given point or body the iron tube is placed thereat, and the heat, causing the enclosed platinum and iridium to expand, increases the electrical pressure of the contact. The principle involved is that by increasing the pressure in this manner at any part of the circuit increases the total strength of the conducted current. Thus, the relative increase in this respect may be measured in the galvanometer, whose readings, within thermometric range, have already been determined for several known temperatures, enabling the discovery of the ratio on which the current conductivity of the circuit increases with temperature rise per degree. There are several other varieties of pyrometer, based on as many different physical and mechanical properties of matter, but the one described—it is known as Chatelier's pyrometer after its inventor—seems to be the most philosophic and reliable.

Heat Efficiency: Theoretical and Practical.—From the facts thus far set forth it may be understood that the *actual heat efficiency*, which represents "the ratio of heat turned into work to the total heat received by the engine," furnishes the percentage on which is based the calculations for "indicated horse power" (I. H. P.). But, on account of the unavoidable waste of heat, in the first place, and of power, in the second place, in producing and maintaining the conditions of operation within the cylinder—in keeping the temperature within operative limits, and in overcoming the physical inertia of the moving parts—the indicated horse power is always much greater than the delivered horse power (D. H. P.) or brake horse power (B. H. P.), when both are stated in terms of heat units consumed. Owing to the physical properties of gases and to the conditions of waste, which reduce the expansion line from the theoretical adiabatic to a figure very different, the total efficiency, as we have seen, falls from 72 per cent. to 26 per cent. The greatest possible available percentage, however, due to the nearest practicable approach to ideal conditions, would represent a mean between these. Consequently, we may derive the *mean theoretical efficiency*, as the ratio between the actual and the maximum figures, which gives us:

$$\frac{\text{Indicator reading}}{\text{Theoretical efficiency}} = \frac{26}{72} = .361,$$

as the figure representing the greatest possible utilization of heat in the operation of a gas cylinder.

Mechanical Efficiency in Heat Units —Similarly also, the fourth head of efficiency, the *mechanical efficiency*, of a gas engine, represents the ratio between the delivered horse power, as found by Prony brake or dynamometer, and the indicated horse power, the difference in practice being the power lost by general internal friction of the engine. Thus, if the indicated horse power is 10 and the delivered horse power is 8, the ratio is found as follows:

$$\frac{\text{D.H.P.}}{\text{I.H.P.}} = \frac{8}{10} = .80.$$

To state this in terms of heat expended, we find that one horse power is 33,000 foot-pounds per minute, and that 778 foot-pounds equals one thermal unit, which equation expresses the *mechanical equivalent of heat*. Whence, one horse power per minute equals 42.42 thermal units, which is, by the hour 2,545 thermal units. Then 10 H. P. equals 25,450 thermal units and 8 H. P. equals 20,360 thermal units. Whence we have:

$$\frac{20360}{25450} = .80.$$

If, however, 10 H. P., or 25,450 B. T. U. per hour be assumed equivalent to the I. H. P. of a given engine, which is, as we have seen, 26 per cent. of the total fuel efficiency supplied to the engine, we have it that the total theoretical value of the fuel should be 97,884.61 B. T. U., or 38.46 H. P. According to a noted authority, the average of a number of tests of gas engines is as follows:

To the jacket water	52	per	cent.
To loss in the exhaust	16	"	"
To loss in radiator, etc	15	"	"
To useful work (D. H. P.)	17	"	"

FIG. 162.—Four-Cylinder, 10 H. P. "Buffalo" Gasoline Engine for Motor Vehicle Use. The gearing of this motor renders it non-vibrating, as guaranteed, while, by the "shifting-spark" system of governing, the speed may be varied from 100 to 1,500 R. P. M. without changing the motion of the valves. This is an exceedingly flexible system of governing. The cylinder head is water-jacketed; the firing stroke in the four cylinders follows consecutively, thus securing perfect balance: the inlet valves are positively operated, thus enabling a wide range in adjusting fuel charge ratios. On account of the four-cylinder positive igniters, the engine is very easy to start.

This shows a total of 83 per cent. lost for efficient mechanical work, or useful, at best, only for maintaining necessary interior conditions. Accepting these figures as fairly typical, we find for 10 I. H. P., or 26 per cent., a total of 97,884.61 thermal units, or 38.46 H. P. by the hour, theoretically fed to the cylinder in shape of fuel mixture. Giving the other quantities their proper thermal and mechanical equivalents, we have:

52% = 50899.9972 B. T. U. = 19.9992 H. P.
16% = 15661.5376 B. T. U. = 6.1536 H. P.
15% = 14682.6915 B. T. U. = 5.7890 H. P.
17% = 16640.3837 B. T. U. = 6.5382 H. P.

100 97884.6100 38.4600.

This example, drawn from actual averages, represents only 6¼ B. H. P. on 10 I. H. P., but in general practice the figures are usually given as about 8 to 10.

Another authority, as quoted by several writers, finds the following results from a series of experiments with a 125 H. P. gas engine: At full load 26 per cent. of the heat energy becomes converted into mechanical energy, 44 per cent. lost through the exhaust and by radiation and 30 per cent. absorbed by the jacket water. At three-quarter load, the figures become 25, 38 and 37 per cent. respectively; at one-quarter load, 18, 28, 54, and, when running free, 10, 32 and 58 per cent. These figures show that the percentage of loss through the exhaust increases as the jacket loss decreases. Other recorded tests show similar figures.

To discover the calorific value of a gas by the cubic foot, or by any other unit of cubic or weight measure, the following formula has been laid down for determination by the cubic amount consumed in raising the temperature of water by the degree:

$$H=\frac{W\,T}{G},$$

in which H is the calorific value;
W " " quantity of water by volume;
T " " difference in temperature of the water supplied and the water heated;
G " " quantity of gas, in cubic feet, required to raise the water to the given temperature.

Supposing that in a given case, W is equal to 1 liter (.22 gallon); T is equal to 18, or the difference between 27°, the acquired temperature, and 9°, the initial temperature of the water; and G, as measured by a gas meter, or other suitable method, equals .190 cubic foot. Then:

$$H = \frac{1 \times 18}{.190} = 94.73 \text{ thermal units.}$$

as the gross calorific value per cubic foot of the particular mixture of gas and air used for the experiment. The *net value* is usually estimated at about 15 per cent. of the gross for most fuel gases, as found by the average of calorimeter tests. Whence, since 15 per cent. of 94.73 is about 14.21, the net value here is 80.52 calories, which indicates the percentage of heat units actually efficient in raising the temperature of the water.

Calorific Value of Fuels.—As given by reliable authorities, the calorific value of several common hydrocarbon fuels, as expressed in thermal units, is as follows:

	Per Pound.	Per Cubic Foot.
Marsh gas ($C\,H^4$)	23,594	1,051
Benzine ($C^6\,H^6$)	18,448	——
Acetylene ($C^2\,H^2$)	21,492	868
Ethylene ($C^2\,H^4$)	21,430	1,677
Natural gas	——	480 to 590
Illuminating coal gas	——	620 to 950
Water gas (average)	——	710

Having ascertained these facts, we are prepared to determine the thermal efficiency of the engine, or the ratio of heat utilized, as compared with the total heat equivalent of the fuel absorbed. For this purpose the following formula is given by Goldingham:

$$E = \frac{42.63 \times 60}{C\,X},$$

in which C expresses the fuel consumption per B. H. P. per hour in pounds, and X the calorific value of the fuel per pound in thermal units.

Although the constant 42.63 should vary somewhat according to the figures for heat and power equivalents as used by other authorities we may use this formula for approximate figures. By the table of percentages given above, we find that for each B. H.

P., or 2545 B. T. U., 5.88 H. P., or 14964.60 B. T. U., are expended. Since gasoline contains 21,900 B. T. U. per pound, we find that this average figure gives us 0.683 pounds fuel consumption per B. H. P. per hour. Then, by the formula, we have:

$$E=\frac{42.63\times 60}{.683\times 21900}=\frac{2557\text{-}80}{15157.7}=0.1687.$$

as the approximate thermal efficiency percentage. This figure agrees with the average percentage for B. H. P., given above, and, as may be seen, can be found by knowing simply the rate of fuel consumption and the B. T. U.'s per pound.

Determining Calorific Values.—Knowing the specific heat of a given gas at constant volume, the calorific value in thermal units may be discovered as follows, in order to estimate the thermal efficiency of an engine:

$$H=C\ (T-t).$$

In this formula H is the calorific value in thermal units; C, the specific heat at constant volume; T, the temperature of explosion, and t, the initial temperature. The specific heat for a 9 to 1 mixture of air and coal gas being 0.1846; a typical explosion temperature 2,764°, absolute, and an average compression temperature, 921°, we have 340.21 thermal units per pound of the initial charge, which is equivalent to 264683.38 foot-pounds, and

$$\frac{264{,}683.38}{33{,}000}=8.02\ \text{H. P.}$$

Determining the Explosion Pressure.—The maximum, or explosion, pressure of a gas-engine is equal to the ratio between the compression and maximum temperatures multiplied by the compression pressure. Thus:

$$\frac{Ct}{E\,t}\times C\,p=E\ p.$$

Substituting the values given above for a given engine, we have

$$\left(\frac{2764}{921}=3\right)\times 68.86=206.58\ \text{pounds,}$$

which, as may be seen, is the same as formerly given in Chapter XXIV. (page 348):

$$P'' = \frac{T'' P'}{T'}.$$

In order to estimate the mechanical efficiency of a given engine we must, as shown above, know the delivered horse power. While there are numerous ways of calculating this, the simplest and readiest formula is as follows:

$$\frac{D^2 \, L \, R}{18{,}000} = \text{D. H. P.}$$

which means that the square of the piston *diameter* in inches is to be multiplied by the *length* of the stroke in inches and the number of *revolutions* per minute of the fiy-wheel, and the product divided by 18,000. This denominator is given by Roberts for a four-cycle gasoline engine. For ordinary four-cycle gas-engines the figure is 19,000. For two-cycle engines operated by gasoline the denominator is given as 13,500; for other types, as 14,000.

To apply this formula we will take a highly efficient three cylinder gasoline vehicle motor with proportions, as follows: The piston diameter is 4.5 inches; the stroke is 4.5 inches; the number of revolutions per minute is 600. Then, substituting, we have:

$$\frac{20.25 \times 4.5 \times 600}{18{,}000} = \frac{54{,}675}{18{,}000} = 3.03 \text{ H. P.}$$

Calculating for the three cylinders we have the formula:

$$\frac{D^2 \, L \, R \, N}{18{,}000} = \text{H. P.}$$

in which N is the number of cylinders. Whence:

$$\frac{54{,}675 \times 3}{18{,}000} = 9.11 \text{ H. P.}$$

This figure is a good average for the formula, although as the writer is assured by the manufacturer of the engine, 10½ D. H. P. has been obtained by actual brake tests.

Similarly, on the basis of these figures, we may calculate the mechanical efficiency per cubic inch of piston displacement, or fuel capacity, as follows:

$$\frac{33{,}000 \times 3.03}{15.904 \times 4.50 \times 300} = \frac{99{,}990}{21{,}470.4} = 4{,}658.$$

In this equation, 15.904 represents the area in inches of a 4.5 inch piston; 4.50 represents the length of the stroke; 300 the number of explosions per minute. The numerator, representing the figure for 3.03 H. P. in terms of foot-pounds per minute, is divided by the product of the denominator terms to give the foot-pounds per cubic inch of stroke space. The result is verified by performing the following operation:

$$\frac{15.904 \times 4.50 \times 300 \times 4.65}{33{,}000} = \frac{100009.1232}{33{,}000} = 3.03,$$

in which the figure for foot-pounds is multiplied by the cubic content in question and the number of efficient strokes per minute in order to obtain an expression in the numerator, as in the denominator, for foot-pounds per minute. The result of the indicated division is the delivered horse power.

CHAPTER NINETEEN.

ON ESTIMATING THE HORSE-POWER OF GAS ENGINES.

Conditions of Efficient Operation.—Following along the lines so far laid down, we find six conditions of high efficiency: 1. The fuel mixture should be carefully proportioned, in order to enable rapid ignition and full utilization of heat. 2. The pressure of compression should be high, in order to enlarge the range of temperature rise at explosion. 3. The wall surface of the clearance, or combustion chamber, should be as small as practicable, in proportion to its required volume, in order to lower the absorption of the heat of combustion and raise the mean wall temperature, facilitating compression. 4. The stroke should be as short as is consistent with good design, in order to reduce the wall surface to which the expanding gas is exposed, with consequent economy of heat and power. 5. The speed of the piston should be high, in order to transform the heat into work with the greatest possible rapidity, also reducing the period of contact between the expanding gases and the cylinder walls. 6. The temperature and rate of circulation of the jacket water should be adjusted, in accordance with careful observation, in order that the temperature of the cylinder may be kept within the required limits, without also absorbing too great a quantity of heat.

The Time Element in Power Estimates.—In the determination of horse-power the *time* element is an important item in all formulæ. This is true because the power to be calculated produces motion and is not simply a static pressure to be measured in terms of pounds weight. In calculating for a gas-engine, also, it is important to remember that the power efficiency increases with the rate of motion, being expressed in terms of revolutions per minute of the fly-wheel or crank shaft. Thus, a given engine running with low gas supply or high load may be able to rotate the fly-wheel only 200 times per minute, while, with full gas supply, or at average load, it can produce as many as 2,000 revolutions per minute. Furthermore, the available power decreases as does the number of revolutions per minute, while, as has already been indicated, the rate of gas consumption per unit of work is increased. Thus it is important to know, in making estimates for horse-power, whether the engine in question is running free or under load. This fact is generally specified in reports on engine power and operation, and is considered in several formulæ.

Engine Dimensions in Power Estimate.—Next to this, the most important consideration refers to the dimensions of the piston and cylinder and the length of the stroke. For, since these figures indicate the power capacity of the engine, in point of the quantity of fuel consumed, and the power developed by explosion, as acting on the reciprocating parts, they, together with the ascertained rate of motion, are in ratio to a figure equivalent to an average ratio between the operative dimensions of the cylinder—these are given above in Roberts' formula for D. H. P.—and the delivered horse-power. For four-cycle gasoline engines this average denominator is given as 18,000, and the figures resulting from the indicated division are average ones. The formula is further verified in the fact that the piston diameter and length of stroke are in discoverable proportion to the D. H. P. and the number of revolutions of the flywheel. So that an engine giving, say, 35 D. H. P. at 600 revolutions per minute, with a fuel whose thermic value is known, must have a certain diameter of piston and length of stroke. These proportions need not be further specified here.

The Mean Effective Pressure.—In making more definite calculations on the power of a gas-engine there are four points to be considered: 1. How great is the mean effective pressure per square inch on the piston during the power stroke? 2. What is the area of the piston? 3. What is the length of the stroke? 4. What is the number of explosions per minute? The ratio between the product of these factors and 33,000 gives the I. H. P. per minute. Thus:

$$\frac{\text{Pressure} \times \text{area} \times \text{stroke} \times \text{E. P. M.}}{33{,}000} = \text{I. H. P.}$$

To reduce this ratio to a practical formula we take the product of the mean effective pressure of the power stroke; by the area of the piston *in square inches;* by the length of the stroke in feet; by the number of explosions per minute, and divide by 33,000, which figure expresses the number of foot-pounds per minute per horse-power. Thus:

$$\frac{P\ A\ S\ E}{33{,}000} = \text{I. H. P.}$$

Taking the figures for the gasoline engine calculated above, which gave 3.03 D. H. P., we have:

$$\frac{80 \times 15.904 \times .375 \times 300}{33{,}000} = \frac{141036}{33{,}000} = 4.27 \text{ I. H. P.}$$

In this operation the figure 80 represents a fair average of mean effective pressure for high-grade gasoline engines under 25 H. P.; 15.904 is the area in square inches of a piston 4.5 inches diameter; .375 is the expression in feet for 4.5 inch stroke, and 300 the number of explosions per minute. The result, 4.27 I. H. P., is a fairly proportionate figure for indicated horse-power of this engine, since, taking 3.03 as 17 per cent., it is equivalent to 22.8 per cent. In order to get anything like exact figures, it is necessary to determine the mean effective pressure, which can be most readily discovered with an indicator tracing, such as has been depicted above. The methods of measuring are either by ruling *ordinates* at right angles to the atmospheric or base line of the diagram and taking the average of their length, or by use of an instrument called the planimeter.

Estimating by the Indicator Diagram.—As may be understood from the term itself, the mean effective pressure is an average expression for the degree of pressure in pounds brought to bear upon the piston of a cylinder during the power stroke. It has been well defined as "the difference between the average gauge pressure shown by the expansion line and that shown by the compression line, minus the back pressure of charging or suction." As all these operations are depicted on the indicator diagram an average of its proportions will yield the desired result. On the method of calculating by ordinates we proceed as follows: A number of parallel equidistant lines are ruled on the diagram at right angles to the base line, and their lengths measured between the points where they intersect the compression and the expansion curves. The lengths thus found are added together and the sum divided by the number expressing their number, in order to obtain an expression for the average length. This result is then multiplied by the pressure of explosion as recorded by the indicator tracing. If, then, the average length of the ordinate lines is two inches and the indicated pressure at explosion is 300 pounds, the result would show a mean effective pressure of 600 inch-pounds or 50 foot-pounds.

A simpler method is to find the mean ordinate of the diagram by the following process: Find the centre of the diagram figure on the base line; erect a line perpendicular to the base from that point; draw another line from the base so that it touches the expansion line at about the point of exhaust valve opening, at such an angle that the two parts on either side of the centre line will be equal, measuring from a perpendicular on the explosion line on the one side, and from another touching the "toe" of the tracing on the opposite side. The portion of the centre line thus laid off by intersection is the mean ordinate, which, multiplied by the indicated pressure, gives the M. E. P.

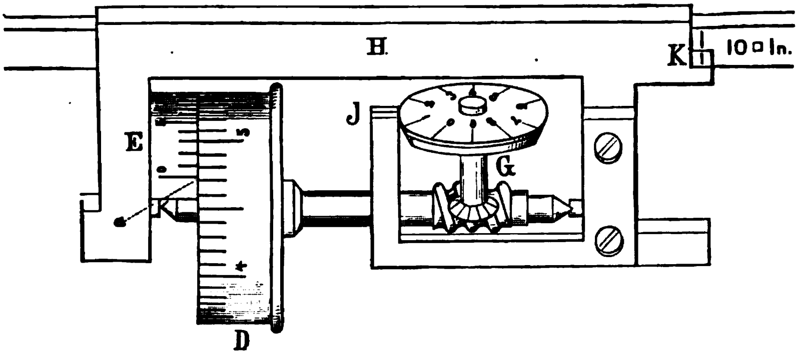


FIG. 163.—Recording Mechanism of a Typical Planimeter. D is the graduated drum, divided into 10 numbered sections, each representing 1 square inch, and 10 intermediate points, each equal to 1-10 square inch. E is the vernier, which is divided into 10 equal parts, each representing 1-100 inch. The wheel, G, records the number of revolutions of the drum, D, each of its graduations being equivalent to 10 square inches, as measured at the post, J. The measurement on the positions shown gives 10 on disc, G; 4 on the roller, D, which is the last number passing zero on the vernier; 7-10 for the smaller graduations on D, as shown by line, *a*, at zero on the vernier; and 8 on the vernier, as representing the scale point on the vernier opposite to the nearest number on D. The result is, therefore, 14.78 square inches.

Calculating Diagrams by Planimeter.—A more exact method is by the use of the planimeter, one form of which is shown in an accompanying figure. Briefly, it consists of two arms pivoted together. One of them is arranged to be secured to the board, the other carries a tracing point on the free end and a graduated wheel arranged to indicate square inches and tenths of an inch and a vernier to indicate hundredths. Having secured the instrument to the board in such a manner that the tracer may be set upon the lines of the diagram, the graduated wheel is adjusted so that the point registers zero. Then, moving the tracing point over the entire line of the diagram in the same direction as the hands of a watch, the wheel is made to travel accordingly, and to register the area of the circumscribed space. If, now, the largest figure on the graduated wheel is 2, and the number of graduations thereafter passing zero on the vernier be 6 and the opposite graduation on the vernier be 4, we have the figure 2.64 as the area of the diagram in square inches. This figure should then be divided by the extreme length of the diagram, which may be taken as 3.2 inches, which gives the quotient 0.821875 as the average height of the diagram. This figure multiplied by the scale of the spring, used in the indicator making the diagram, gives the figure for mean effective pressure. If this figure be 40, for example, we have as the result 32.88, as the expression for mean effective pressure. From this it may be understood that the size of the diagram, or the length of the circumscribed line varies according to the strength of the spring geared to the tracing pencil, and, according to the engine pressure bearing upon that spring. Thus a weak spring with a moderate pressure would give a very large diagram, while a strong spring and a high pressure would give one no larger. Thus the spring strength or scale is an item in calculating the effective pressure of the engine giving the diagram.

The indicator is fully explained in the chapter on steam.

Determining the Speed.—Knowing the mean effective pressure of the engine, the only undetermined element in the above formula is the speed, expressed as revolutions per minute of the fly-wheel, which being halved gives the number of explosions per minute for a four-cycle engine. The readiest method is to test with a tachometer (speed-meter), an instrument consisting of a rod which is pressed against the end of a rotating shaft, so as to be rotated with its motion, and record the number of such revolutions per given time on a dial.

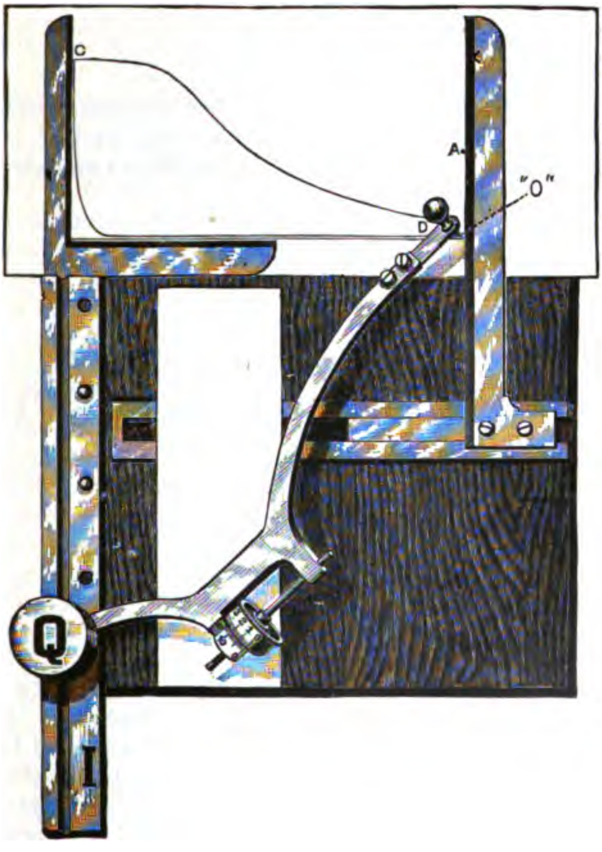


FIG. 164.—Method of Averaging a Diagram with one Type of Planimeter. The pin, Q, is set in the groove, I. The card is held on the board between clamps, C and A. The tracing point, O, is set at point, D, and the arm moved clockwise, the vernier and drum having been set at zero.

Average Figures for Speed—A fair average figure may be substituted in the formula given above for indicated horse-power, when the revolutions per minute are not known. It may be found as follows: Since the piston speed of most motor carriage engines running at full power is somewhere between 400 and 600 feet per minute, we may take the average of 500 feet, multiply it by 12 to reduce to inches and divide by twice the length of the stroke in inches. Thus:

$$\frac{6,000}{2\,S} = \text{R. P. M.}$$

Twice the stroke is used because that expresses the space covered by the piston in each revolution of the fly-wheel. Substituting this formula in the typical engine mentioned above, we find that:

$$\frac{6,000}{9} = 666 \text{ revolutions per minute,}$$

which is very nearly the correct figure.

Roberts gives a more complicated formula, as follows:

"The following formula representing average practice among manufacturers will be found valuable in making the first approximate calculation:

"Let H=the D. H. P. of the engine;
Let R=the revolutions per minute;
Then for a four-cycle engine

$$R = \frac{380}{(H)^{.21}}$$

"In order to solve the above equation it is necessary to use logarithms. Suppose it is desired to find the speed of a 15 H. P. four-cycle engine. Take a table of logarithms and find first the logarithm of 15, which is 1.176091; multiplying by .21 the result is .24697911, which is the logarithm of 15 to the .21 power. The logarithm of 380 is 2.579784; substracting the logarithm of $(15)^{n}$ from this, we have 2.332705, which is the logarithm of 215.1. The proper speed for this engine is 215 r. p. m. or thereabout."

Estimating Power Without Diagrams.—The formulæ given above depend for exact results on the measurement of indicator diagrams. But it is possible to compute roughly without these. An authority quoted previously gives the following:

"When an estimate of an engine's capacity is desired, and no diagrams are obtainable, the approximate horse power attainable in the cylinder may be found by means of the formula:

$$\frac{E \times V\,C}{1{,}000} \times \left(\frac{P'' - PE \times RE}{120} - \frac{PC - P^1 \times RC}{140} \right) = \text{H. P.}$$

"No doubt the formula will seem rather complicated at first glance, but its application is by no means difficult. Stated as a rule it reads as follows:

"Multiply the *exhaust pressure* by the *expansion ratio,* and subtract the product from the *explosion pressure;* divide what is left by 120, and call the result the '*first quotient.*'

"Multiply the *initial pressure* (about 13.2) by the *compression ratio,* and subtract the product from the *compression pressure;* divide what is left by 140, and call the result the '*second quotient.*'

"Subtract the *second quotient* from the *first quotient,* and multiply the remainder by the *number of explosions per minute* and by the *clearance volume;* divide this result by 1,000."

By attentively reading this rule the quantities may be readily recognized on the formula where they are designated by their initial letters.

The same authority gives another formula based on average figures as follows: Take the figure for the difference between the *exhaust pressure* and the *initial pressure* (13.2). Multiply it by a figure representing the average found by adding the *compression ratio* and *expansion ratio* and dividing by 2. Subtract the product thus found from the figure for *pressure rise,* which is to say the difference between the *pressure of explosion* and the *pressure of compression.* Divide the remainder by 10. Multiply the *quotient* thus found by the product of the *number of explosions* per minute and the *clearance volume,* and divide the product by 10,000.

Expressed graphically this gives us:

$$\frac{E \times V\,C}{10{,}000} \times \frac{(P'' - P\,C) - (P\,E - P' \times \frac{rc + re}{2})}{10} = \text{H.-P.}$$

Estimating the Power by Prony Brake.—The most satisfactory method of testing the effective power of an engine is by the use of Prony's brake, one form of which is shown herewith.

Briefly, it consists of a band of rope or strip iron—the latter is the arrangement shown—to which are fastened a number of wooden blocks, several carrying shoulders to prevent the contrivance from slipping off the wheel rim. Being applied to the circumference of the fly-wheel the brake band is drawn tight, as shown, so that the blocks press against the surface all around. The brake, thus formed, is prevented from revolving with the fly-wheel, by two arms, attached near the top and bottom centres of the wheel, and joined at the opposite ends to form a lever, which bears upon an ordinary platform scale, a suitable leg or block being arranged to keep its end opposite to the centre of the shaft. By this arrangement the amount of friction between the brake band and the revolving wheel is weighed upon the scales. For since the brake fits tightly enough to be carried around by the wheel, but for the arms bearing upon the scale, the amount of frictional power exerted by the wheel in turning free within the blocks may be transmitted and measured, just as would be the case were a machinery load attached, instead of a friction brake.

The Factors in the Formulæ.—Accordingly, the factors in estimating the power developed are: (1) The circumference of the wheel; (2) the length of the leverage, measured on the line drawn from the centre of the rotating shaft to the centre of the scale platform; (3) the number of revolutions per minute; (4) the weight in pounds registered by the scales, less the static weight of the brake lever arms and block resting on the platform. With this form of Prony brake the formula for delivered horse-power is as follows:

$$\frac{W \times N \times L \times C}{33{,}000} = \text{B. H. P.}$$

in which W is the net weight as shown by the scale; N, the number of revolutions per minute; L, the length of the leverage; C, the circumference of the braked fly-wheel. Their product gives the number of foot-pounds developed; the quotient of the indicated division by 33,000 gives the efficient horse-power. If, therefore, a given engine has a fly-wheel of 16 inches diameter, revolving at 600 revolutions per minute, and giving 27.5 pounds at the scale, with a leverage of 5 feet, we have, according to the above formula:

$$\frac{27.5\times600\times5\times\frac{3.14159\times16}{12}}{33{,}000}=\frac{346830.57}{33{,}000}=10.51 \text{ horse power.}$$

The diameter, 16 inches, being multiplied by 3.14159, the expression for the ratio between the circumference and diameter of a circle, gives 50.2655 inches, which, divided by 12, gives 4.189 feet approximately.

Other Forms of Prony Brake.—In some forms of Prony brake the block-bearing rope or band, instead of being secured as shown in the cut is attached to the floor and ceiling—two dynamometers or spring balances being interposed. Thus in the formula for estimating with this form, the item of leverage length is omitted, the expression being:

$$\frac{\text{W}\times\text{N}\times\text{C}}{33{,}000}=\text{D. H. P.}$$

As may be readily understood the scale weight in this case would equal the product of the weight and leverage length with the other formula.

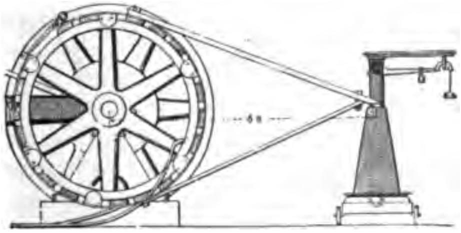


FIG. 165.—Common Form of Prony Brake, for testing the D. H. P. of an engine. An iron band shod with wooden blocks is drawn tightly around the circumference of the fly-wheel. To this two arms are attached, the other ends of which bear upon the scale platform, as shown. It is necessary that the scale platform be raised to the same height as the centre of the fly-wheel shaft. The length of leverage is indicated as 5 feet 3 inches, the diameter of the wheel being 3 feet. These two factors, the R. P. M. and the recorded weight, are the essential elements in the determination of power as by the above formula.

CHAPTER TWENTY.

ON CARBURETTERS AND VAPORIZERS.

Carburetting Devices of Various Descriptions.—In operating a gasoline vehicle motor, it is essential that the liquid fuel be transformed into a gas, so as to be fed to the cylinders with a suitable mixture of atmospheric air. This process is performed by a device known as a carburetter, which consists in general of a vessel into which a small amount of liquid gasoline is admitted as required, and being there vaporized by air, which is passed through it or over it, and by the suction of the piston causes, the gasoline to rise through a small orifice and mix with the passing air current in the form of spray. There are two common forms of carburetter; the surface carburetter, in which a current of air passing over the surface of the liquid gasoline, absorbs a certain portion of it, and the float feed carburetter, or sprayer, in which a current of air is drawn by the suction of the piston stroke, causing a spray to rise from the gasoline through a nozzle, the level of the liquid being continually maintained by a float controlling a needle valve to the supply tank. A third form, the filtering carburetter, has several points of resemblance to the simple mechanism sometimes employed for vaporizing gasoline for the purpose of illuminating houses. The gasoline is contained in a suitable receptacle, which stands in a cistern filled with water to a certain level; a cylindrical cover, balanced by a weight passing over a pulley, is suspended in the cistern over the gasoline receptacle, and is caused to rise by the pressure of air that has been pumped through the liquid gasoline and has absorbed a sufficient portion of it to render the mixture of air and gas inflammable. This mixture is then fed to the pipes leading to the gas burners in the house.

Air thus charged with the vapor of gasoline, or other volatile spirit, is said to be carburetted. In the practical construction of carburetters for gasoline vehicle use, a number of points must be considered, since in the use of such a device of any pattern, the elements of jar and vibration likely to disturb the operation of the instrument, must be provided against. Also, for numerous other reasons, only a portion of the total fuel carried is acted upon by the air current at one time in the carburetters.

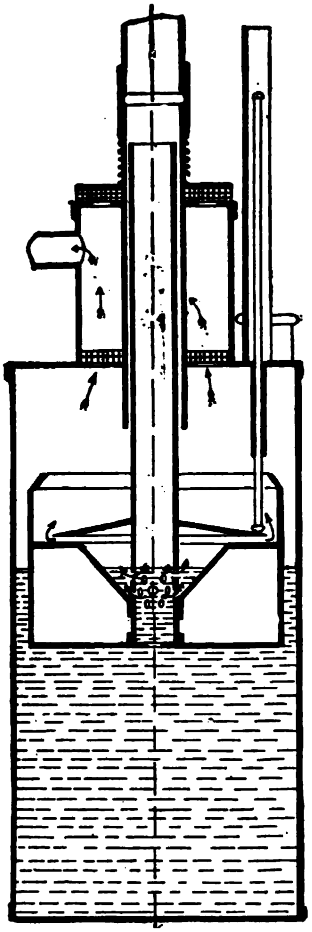


FIG. 166.—The Daimler Surface Carburetter, used on the early Daimler cycles and carriages.

Daimler's Surface Carburetter.—The idea of using liquid fuel for a gas engine, and carburetting it by a suitable instrument, was one of the improvements introduced by Gottlieb Daimler.

Daimler's carburetter, a section of which is shown in an accompanying illustration, was used on the earliest motor vehicles, tricycles and carriages made by him. It was a very efficient instrument in its day, but represents a style of construction that has been entirely superseded. It consisted of an elongated cylindrical vessel, which was partially filled with gasoline. Upon this liquid was a hollow cylindrical float, the shell of which was slightly depressed upon the upper face, so that the gasoline rising through the hollow in the centre could be readily exposed to the action of the air, drawn through the vessel by the suction of the piston. The float also carried a vertical tube, which reached upward through the top of the inclosed cylindrical vessel, sliding freely in a second tube of larger diameter, in order that the float might rise or fall to the level of the gasoline. In the top of the cylindrical vessel was also set a cylinder of somewhat smaller diameter, having a perforation in its top admitting atmospheric air, and having its base connected with the interior of the main cylindrical vessel. These openings at both top and bottom could be regulated by rotary valves. At the left-hand upper side of this cylinder was a vent, which was connected with the combustion chamber of the cylinder. The operation was as follows: When the piston began the suction stroke, air was drawn through this vent, some of it coming through the upper openings already mentioned, and another portion through the vents at the base, which connected it with the main body of the instrument. The air from within this main cylinder was drawn downward to the operating tube; the greater portion of it, as may be understood from the figure, passing through the small holes in the base of the tube, thus upward through the gasoline contained within the central depression of the body of the float, causing vaporization and thoroughly charging the air drawn into the cylinder. As may be seen from the illustration, the upper cylinder, which is in connection with the combustion space, has its vents covered with wire gauze; the object of this was to prevent the ignition of the contained gasoline and vapor, in case of backfiring in the cylinder.

Maybach's Float Carburetter.—On later vehicles made by Daimler were used the balanced float feed carburetters invented by his collaborator, William Maybach. As first constructed by him, this style of instrument was the simple device shown in the accompanying cut. The float, *A*, contained within a small vessel connected by a tube, *B*, with the valve chamber of the cylinders, *F*, bears upon its upper face the spindle of a needle valve, which regulates the rate at which the gasoline is admitted to the carburetter through the tube shown at its top. This is the simplest form of the float feed carburetter. The action is as follows: When the piston in the cylinder, *F*, is making its suction stroke, the valve, *D*, is opened inwardly, compressing the spring, *E*, carried on its stem, and giving admission to atmospheric air, as indicated by the arrows. Since, however, the end of the tube, *B*, which is reduced to form the spraying nozzle, occupies the greater part of the air inlet, the strong spray of liquid gasoline is drawn up by suction and mixes with the atmospheric air in the valve chamber, *C*, the proportions of the mixture being determined by the dimensions of the apertures admitting additional air into the cylinders. The defects of this instrument are obvious; for since the float, *A*, is not balanced in any manner, its action was liable to be uncertain through the vibrations of travel, with the result that its regulation of the level in the float chamber would be uncertain if the valve stem were not wrenched or broken so as to render the machine useless. Largely from the considerations just noted, later types of the float feed carburetter have been constructed with a very elaborate and reliable adjustment to secure the maintenance of the desired level and the certain action of the

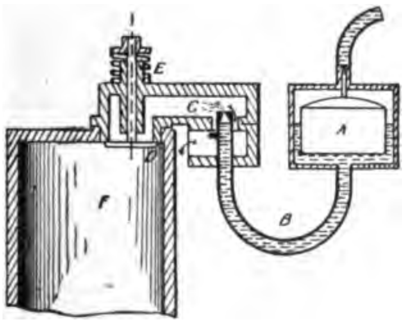


Fig. 167.—Maybach's Original Float Feed Carburetter. A is the hollow float carrying the spindle of the needle valve at its top; B, the tube leading into the inlet valve space; C, the spraying nozzle; D, the inlet valve; E, the inlet valve spring; F, the cylinder space.

needle valve. The method of admitting air to mix with the gasoline spray under suction of the piston has also been so improved as to permit of considerable adjustment of the proportions in the fuel mixture.

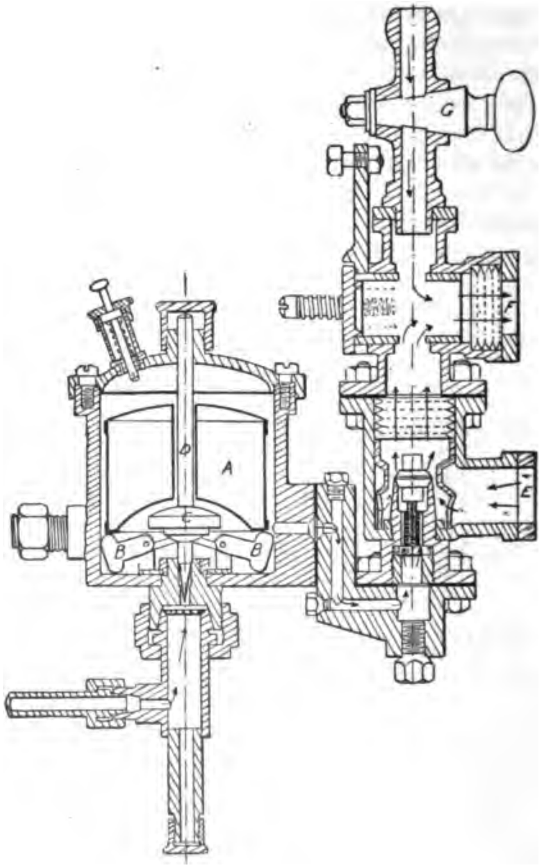


FIG. 168.—The Longuemare Float Feed Carburetter. A is the float; B, B, the weighted levers controlling the needle valve; C, the weight holding the needle valve closed while the lever is right in the float chamber; D, the spindle of the needle valve; E, air inlet; F, pipe communicating to combustion space of cylinder; G, cock for admitting additional air supply.

The Longuemare Float Feed Carburetter.—The Longuemare carburetter, shown in an accompanying illustration, is one of the most elaborate variations of the Daimler-Maybach type.

The carburetter chamber contains the float, *A*, through which passes the stem of the needle valve, *D;* this needle valve, however, is not attached to the float as in the earlier model, but is normally held in place by the weight, *C*, which holds the port leading to the gasoline tank normally closed. On either side of the weight, *C*, is fixed a small lever in such a fashion that when the liquid gasoline is at the required level and the float in the raised position, they are also held up by the weight, *C*, bearing upon their inner arms. When, however, the level falls, the float, *A*, bears upon the pivoted weighted arms, *B* and *B*, at the opposite extremities, pressing them downward, as shown in the illustration, and causing the weight, *C*, carrying the valve, *D*, to be raised upward, thus opening the inlet for the liquid gasoline until the normal level is once more restored. The mixing chamber shown in connection with this type of carburetter is considerably more elaborate than the one used with the Maybach just described. The tube, *F*, leads to the combustion chamber of the cylinder, and when the piston is making its suction stroke atmospheric air is drawn through the tube, *E*, passing around the adjustable valve-shaped nozzle leading from the float chamber. This valve-shaped nozzle is of interesting construction, consisting of a head having the general form of a mushroom-valve, to the base of which is a threaded stem, permitting of adjustment in the size of the orifice, through which the gasoline spray is drawn by the suction of the piston. Directly above this valve-nozzle are fixed several layers of wire-gauze, through which the carburetted air passes on its way to the vent, *F*. At the point, *F*, as shown, there are several other layers of wire-gauze. Their object is principally to prevent all danger of explosion, or of disablement, to the instrument in the event of burning-back, which is liable to take place if the inlet valves are not arranged to close promptly, or if they should be in any other fashion disabled. The quantity of air admitted to the carburetter through the inlet port, E, is controlled by a cylindrical valve having the same general construction as an ordinary faucet, the opening of which is controlled by the upright arm shown just below the cock, *G*. A still further adjustment of the mixture, particularly when a larger portion of air is desired, may be obtained by opening this cock, *G*, and admitting the air from above. In spite of its complication, this instrument has been very widely used.

The Peugeot Carburetter.—The float feed carburetter used on the Peugeot carriages, although simpler in its general details, has many of the excellent features of the instrument just described. In this also, the needle valve is held on a rod which passes through the body of the float, being also held in a depressed position, so as to close the vent by a weight, which is raised by pairs of pivoted levers under the weight of the float whenever the level sinks below the required point. The mixing tube is connected at the base with the combustion chamber of the cylinder, admitting air through the tube coming in vertical direction from above, the spray being drawn through the nozzle, which is shaded in black. This nozzle is of the ordinary pattern with a reduced mouthpiece. Directly above it is an adjustable sliding valve, controlled by a turn-screw in the wall of the chamber, which varies the quantity of air admitted, and hence also the richness of the mixture. Additional air may also be admitted when desired, through the tube leading from the base of the mixing chamber, controlled by the cock as shown.

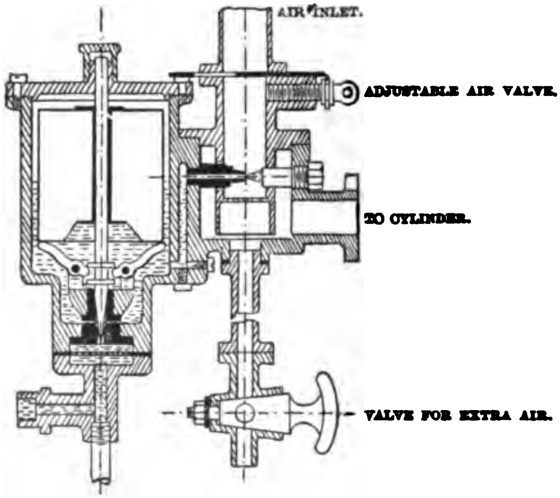


FIG. 169.—The Peugeot Carburetter. This has many points in common with other carburetters, except that the valve levers are differently arranged; the spraying nozzle at the side of the mixing tube, and the air-inlet from above.

The Perfected Daimler Carburetter.—The float feed carburetters used on the later patterns of the Cannstadt-Daimler carriages, and also on those manufactured in France by the firm of Panhard-Levassor, are in several respects similar to the one last described. In these carburetters the spindle of the needle-valve is passed through the tube in the centre of the float. From the top of the gasoline chamber hang two small supports, into which are pivoted levers working in a collar on the valve rod at one extremity of each, and having weights bearing upon the top of the float at the other. The top of the spindle protrudes through the cover of the float chamber and is normally held in a depressed position by a spring bearing upon its end, thus ensuring the closure of the needle-valve and the stoppage of the gasoline feed so long as the desired level is maintained; as soon, however, as this level falls, the weighted extremities of the two levers are depressed, causing the opposite ends to bear upon the collar on the valve spindle, thus forcing it up and opening the valve. In the lettered section of this carburetter, we may see the needle-valve at A, be-

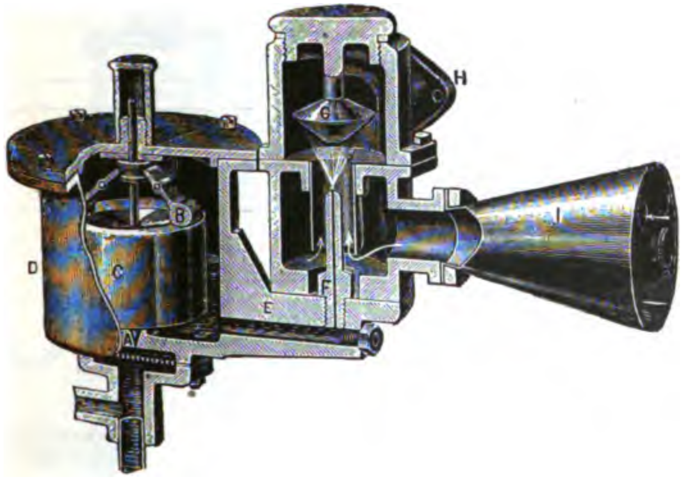


FIG. 170.—The "Phenix" Daimler Carburetter. A is the gasoline needle valve; B, the weighted controlling levers; C, the float; D, the float chamber; E, the gasoline supply tube; F, the spraying nozzle; G, the "mushroom" spray deflector; H, the port leading to the cylinder chamber; I, the air inlet. The air entering the mixing chamber follows the course of the arrows.

low it being shown the supply pipe leading from the gasoline tank, and the layer of wire-gauze interposed just below the entrance to the float chamber. The simple weighted levers are shown at *B*, the hollow float at *C*, the passage for the admission of air at *I*, and the passage leading to the combustion chamber at *H*. The operation is precisely similar to that of the other carburetters already described. Directly above the spring nozzle is fixed a cone, or deflector, *G*, which serves to disperse the spray which is forced against it by air pressure, thus securing, as asserted, the more complete and uniform mixture of air and gasoline vapor.

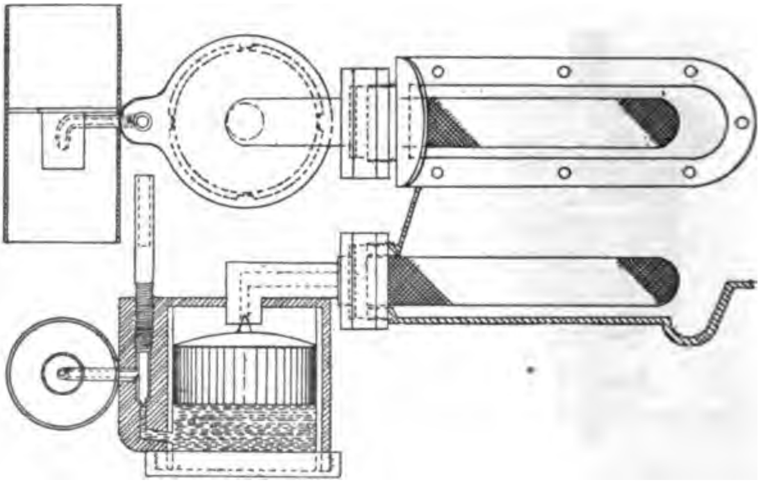


FIG. 171.—The Duryea Float Feed Carburetter or Sprayer.

The Duryea Float Carburetter.—A large proportion of gasoline carriages manufactured in America have, up to the present time, been equipped with float carburetters of the same general construction as those already described. Very exaggerated claims are made by several manufacturers as to the superiority of their own contrivances, but the principal innovation which they can show seems to consist in improved devices for securing undisturbed action of the needle-valve, and for regulating the proportions of the fuel mixture fed to the cylinder. The Duryea carburetter, or sprayer, shown in an accompanying cut, is perhaps one of the simplest among those produced in America. Like the float feed carburetters already described, it has a gasoline chamber in which is placed a hollow cylindrical float; this float, like that used in the earliest form of the Maybach carburetters, carries the point of the needle-valve secured to its top, thereby closing the entrance of the gasoline from the tank through the top of the float chamber, so long as the proper level is maintained within. Unlike the early Maybach carburetter, however, this float is balanced by vertical guides at four points on its circumference, as may be readily understood from the plan and sectional views given herewith. Connected with the float chamber is a vertical passage, whose height may be controlled by an adjusting screw, shown in the figure, and which connects to a spraying nozzle, extending into the tube or passage from atmosphere to the combustion chamber of the cylinder. As shown in the plan view, the spraying nozzle is bent around to a right angle

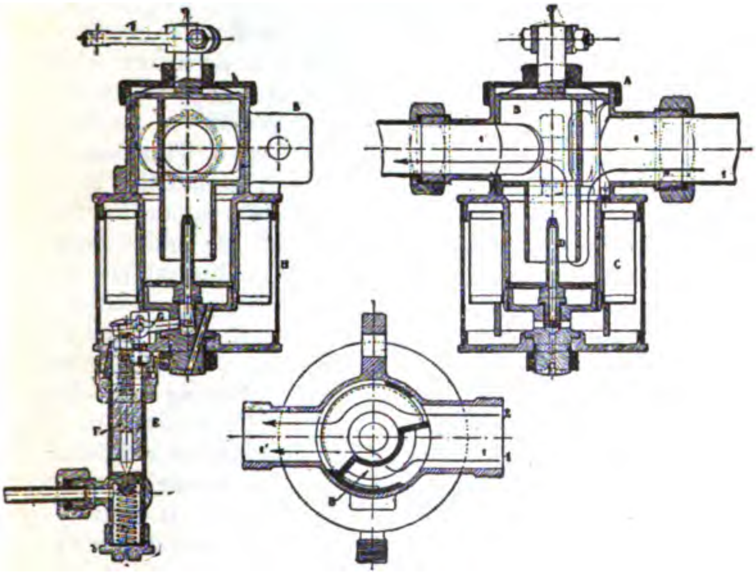


FIG. 172—The De Dion & Bouton Vaporizer. A is the cover of the air chamber; B, the air valve; C, the float; D, the mixing chamber; E, gasoline supply; F, gasoline needle valve; G, valve controlling lever. Arrow (1) indicates course of air through mixing chamber; arrow (2), course of additional air through valve B.

at the end and is enclosed in a short length of small diameter tubing. The inflow of air through the larger tube is controlled by an adjustable rotary valve. The liquid gasoline is fed to the float chamber from the supply tank through a length of tubing encased in a cylindrical cover of wire-gauze, intended primarily to prevent the passage of any impurities which might interfere with the action of the needle valve or clog the small passages leading to the spraying nozzle.

The De Dion Float Carburetter.—The float feed carburetter, used on the later models of the De Dion & Bouton gasoline carriages, combines several features in radical departure from the patterns of carburetter already noticed. As shown in the accompanying sectional plan and elevations, it consists of a cylindrical chamber, *H*, within which is contained a float, *C*. This float differs from the kind used on other carburetters in the fact that it is constructed out of two annular cylindrical shells, united by flanged and soldered ring heads. Its shape, with the hollow space in the centre, makes possible the construction allowing the mixing chamber to be set in the centre of the float chamber, the float surrounding it and sliding against its cylindrical walls. The supply of gasoline is admitted to the float chamber through the adjustable valve shown at *F*, the opening and flow being controlled by the lever, *G*, which, as shown, is in a raised position, thus allowing the needle-valve to be closed, so long as the weight of the float does not bear upon it. The spraying nozzle is located in the mixing chamber, which, as already stated, is entirely surrounded by the ring-shaped float. The gasoline is drawn by suction through this nozzle by the air entering the tube, *t*, and following the direction indicated by the arrow, marked 1 (one) in the plan and right-hand sectional elevation. As shown in the plan, there is also a cylindrical valve, *B*, which may be rotated by the lever, *I*, attached to the stem passing through the cover, *K*, of the upper chamber, *A*. By this handle the charge may be throttled within the desired limits by regulating the inflow of additional air through the tube, *t*, as indicated by the arrow, marked 2 (two) in the plan. This carburetter has the advantage of compactness and simplicity of construction. Another form of float feed carburetter used on De Dion carriages is shown in Fig. 282. It assimilates the common patterns.

The Huzelstein Valve Carburetter.—From the earliest days of the use of liquid fuels for explosive engines, numerous inventors have produced designs of carburetters or vaporizers that operate without the complications of a float chamber and needle-valve, whose opening is regulated by the level of the gasoline contained therein. One of the most typical devices of this description is the Huzelstein, or "Universal," carburetter, shown in an accompanying illustration. It consists of a vertical cylindrical chamber, within which is a valve controlled by a helical spring and hung on a spindle, the upper end of which forms a needle-valve, closing the inlet port for liquid gasoline, shown at the top of the cylindrical chamber. The gasoline from the supply tank

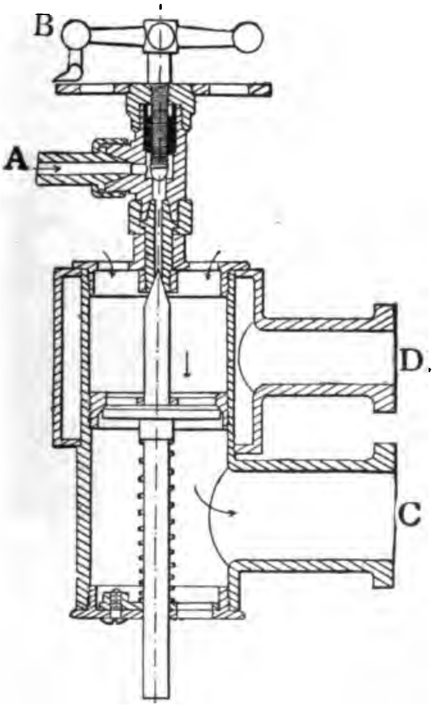


FIG 173.—**The Huzelstein Carburetter. A is the inlet for gasoline; B, the valve controlling inlet; C, the tube leading to cylinder combustion space; D, tube for leading hot exhaust gases around the jacket on the mixing chamber. Arrows indicate entrance for air and course of mixture to cylinder.**

is fed through a tube, *A*, leading to this chamber and having its rate of supply regulated by a needle-valve carried at the end of an adjustable screw shank, upon the upper end of which is the handle, *B*. Connection with the interior of the main cylindrical chamber and the combustion space of the cylinder is had by the tube, *C*. The tube, *D*, is also connected with the combustion space so as to permit the heated products of combustion to circulate through the jacket or passage around the upper part of the mixing chamber above the valve. The suction of the piston operates to open the valve, drawing it from its seat and depressing the helical spring around the lower portion of the valve spindle. This process, of course, opens the needle valve leading from the gasoline feed pipe and permits the inflow of a small quantity of liquid gasoline. This is mixed with the air drawn through the opening indicated by the arrows at the top of the chamber, the process of mixing being perfected by the heat of the vapors passing through the tube, *D*, and around the chamber in connection with it; also, by the friction experienced in passing through the narrow clearances between the open valve and its seat. Between the periodic suction strokes of the piston, the air in the upper portion of the mixing chamber above the valve is made to absorb some of the heat circulating around it, and hence, according

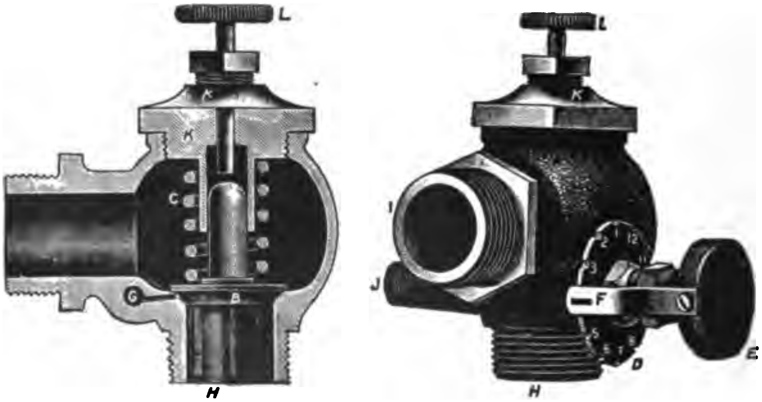


FIG. 174.– The James Valve. B, fuel inlet valve; C, spring controlling B; D is the scale dial showing proportions of air and gasoline; E, the wheel controlling gasoline valve; F, clip or top for holding E in position; G, gasoline supply tube; H, air inlet; I, entrance to cylinder; J, entrance for gasoline; K, cover of valve chamber; L, wheel and spindle controlling tension of spring, C.

to the theory of the inventor, is better prepared to mix perfectly with the gasoline mist. This carburetter has seen considerable use in France and some other European countries.

The James-Lunkenheimer Valve.—Several well-known makes of American carburetters are constructed to operate along the same general lines as the Huzelstein, and, like the majority of American improvements in motor vehicle construction, have the advantage of greater simplicity, strength and compactness. Among these we may mention the James mixing valve, shown herewith. This device consists of a globular valve chamber having three openings or vents, *H*, *I* and *J*. As shown in the sectional view, the opening, *H*, is closed by the mushroom valve, *B*, under tension of the spring, *C*. The passage, *I*, is connected direct to the combustion chamber of the cylinder, and at the suction stroke of the piston, the air is drawn through the tube, *H*, its pressure causing the valve, *B*, to rise from its seat. The air drawn through the passage, *H*, also draws as spray a small portion of liquid gasoline through the tube, *G*, which connects through the passage, *J*, with the gasoline supply tank; thus securing a very good fuel mixture, according as the play of the valve, *B*, and the opening of the tube, *G*, are adjusted. The proportionate amount of gasoline fed into the cylinder through the passage, *J*, of the tube, *G*, is controlled by a needle-valve carried on the spindle at the hand-wheel, *E*, the proportionate opening of the valve being indicated on the graduated disc, *D*, by the position of the clip, *F*. The play of the valve is also regulated by the position of the spindle carried on the hand-wheel, *L*, which is threaded so as to be raised or lowered as required. Mixing valves of this description have been adopted on several makes of American gasoline carriages, notably the Winton, with apparently favorable results.

The Improved Filtering Carburetter.—Another interesting carburetting device, also of American design, and known as the "Auto Carburetter," is shown in an accompanying illustration. Here connection to the gasoline supply tank is had by port, *B*, leading into a simple globular chamber, through which is fixed the spindle of an adjustable needle-valve, controlling the entrance to the cylindrical chamber, *K*, within which are fixed, at a slight incline, eight semicircular pieces of wire-gauze. The gasoline, admitted through the opening of the needle-valve, drips upon these pieces of gauze, any overflow from one falling to that next below it, so that the air drawn through the ports, *C*, opening into the top of the cylinder, becomes thoroughly charged with gasoline mist before reaching the bottom, connection being made with the combustion space of the cylinder through the tube, *G*, which connects direct with another larger cylinder placed outside of the first. The air is drawn through the layers of gauze down through the

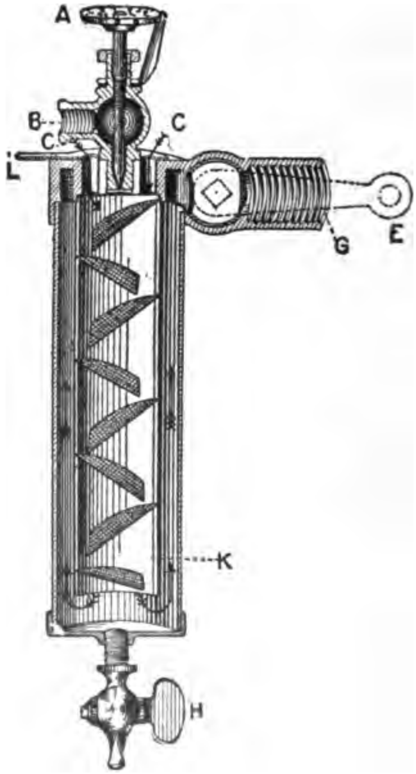


FIG. 175.—The "Auto" Carburetter. A, wheel controlling needle valve; B, gasoline inlet; C, C, air inlets; E, throttle lever; G, pipe to cylinder; H, drip cock; K, inner cylinder containing segments of wire gauze; L, valve controlling air inlets.

inner cylinder to its bottom, then up and around it. The opening of the gasoline inlet tube, *G*, is controlled by a cock, *F*, on the rod, *E*, so that the amount of mixture may be varied or the tube entirely closed. The drain cock, *H*, is fixed at the base of the outer cylinder, so as to carry off any leakage of gasoline or unvaporized residue that might collect within it.

Supplemental Mixing Chambers.—Many of the earlier types of explosive motors for vehicle use were equipped with a mixing chamber in addition to the carburetting device. This mixing chamber in its typical construction, as used on the Benz carriages and some of the Daimlers, consisted of two tubes telescoped together, the inner one of which had longitudinal openings, so that, the further it was pulled out from the outer tube, the larger the amount of air that was admitted with the carburetted mixture under the suction of the piston. To diminish the air supply, the same tube was pushed in. However, in later engines of the four-cycle type, the practice of drawing in atmospheric air, in addition to that coming through the carburetter, has been abandoned, and carburetters are now constructed, as we have seen, with air and gasoline inlet valves that may be adjusted so as to vary the proportions of the mixture passing through the instrument. There is thus but one inlet valve to the cylinder, and that is used solely for admitting the regulated fuel mixture from the carburetter.

Troubles With Carburetters.—Under ordinary circumstances, as in summer or in dry weather, the process of carburetting the liquid fuel, so as to form a mist or vapor, suitable for explosion in the cylinder, is very readily perfected with mineral spirit of the proper quality. It has been found, however, that cold and damp weather are apt to materially reduce the volatility of the liquid, with the result that the power efficiency of the motor is oftentimes reduced nearly one-half. In order to partially combat this difficulty, numerous motor carriage builders, both in America and abroad, have arranged to place the carburetting device in or near the muffler, so that the heat of the exhausted residua of combustion may act to promote the carburettization of the fuel and, as far as possible, neutralize the ill effects due to unfavorable weather or temperature. The device is a desirable feature under any circumstances; since, as has been recognized by numerous inventors, heat materially helps the process of vaporizing—heated air will absorb the vapor of gasoline much more readily than cold air; also heat will ensure the best possible results, even with the use of the poorer qualities of liquid fuel.

Kerosene Vaporizers.—Although for numerous reasons, such as its stench, dirtiness and inferior vaporizing qualities, kerosene has been used successfully in but few explosive engines, propelling motor carriages, the few employing it as fuel have embodied with the vaporizing device certain facilities for so preheating the liquid that the mist formed by the injection of air, under suction of the engine piston, is rendered as rich as possible. This provision is in obedience to the quality of kerosene, which renders it much more readily volatile when heated than when cold—for, although many qualities of this oil have the "flash point," at which inflammable vapors are given off, at a very low temperature, the process is greatly facilitated at higher temperatures, when also many of the heavier constituent elements may be taken up, as mist, by the air passing through, or over, the liquid.

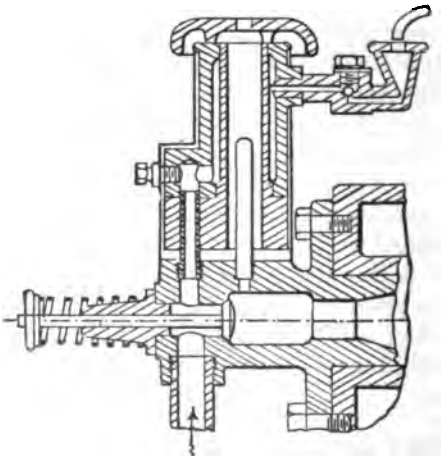


Fig. 176.—The Blackstone Kerosene Vaporizer. As is evident, the oil sprayed in at the right-hand top of the cylinder passes through an annular space around the "chimney" of the hot tube, passing thence to the space behind the inlet valve.

A kerosene vaporizing device is shown in an accompanying cut, which exhibits the construction to advantage. Upon the inlet valve chamber of the cylinder, and around the hot tube igniter opening into it, is set a metal chimney having an annular channel or jacket between its walls and entirely around its circumference. Into this jacket the oil, dripping from a small tube into a funnel at the upper right-hand of the figure, enters with air, also drawn into the funnel by piston suction; both flowing around through the jacket space, which is heated by the flame employed to keep the hot tube incandescent. The heat, acting on the oil and air, serves to break up the former into a mist, which is carried, through the channel at the left-hand lower portion of the annular jacket, to the chamber directly behind the inlet valve, as shown. At the suction stroke of the piston, the oil and air mist is drawn into the cylinder clearance, together with additional air coming through the tube shown at the lower left-hand corner of the figure. The proportions of the additional air supply being adjusted, as desired, the explodability and power of the charge may be regulated to power and speed requirements.

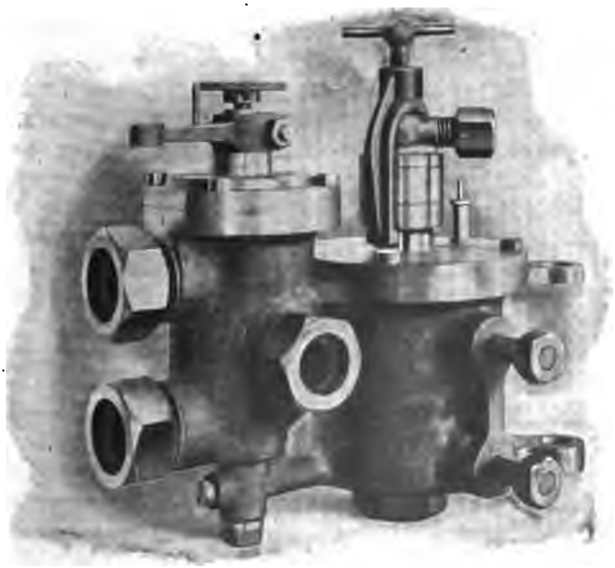


FIG. 177.—A Typical Float Feed Carburetter This cut gives an outside elevation of the instrument shown in section in Fig. 135.

CHAPTER TWENTY-ONE.

ON THE SEVERAL METHODS OF FIRING THE CHARGE IN A GAS ENGINE CYLINDER.

Firing the Charge in Cylinder.—As already stated in a previous section, the fuel mixture of air and gas, after it has been drawn into the combustion chamber of the cylinder, is ignited explosively, thus being compelled to assume its maximum volume, by some source of heat which acts periodically. As also mentioned, there are several methods of accomplishing this result; several of them depending for operation upon the act of compressing the charge.

Firing the Charge by Heat of Compression.—In the Diesel four-cycle engine, the explosion of the charge is accomplished entirely by the temperature produced by the compression stroke. At the suction stroke of the piston, pure atmospheric air is admitted to the combustion chamber, and at the completion of the compression stroke, which in this engine extends all the way to the rear head of the cylinder, it is compressed to about 550 pounds to the square inch, which produces a temperature about equal to the heat of combustion. Very shortly after the beginning of the next out-stroke the fuel charge, which may be gasoline vapor, coal gas or atomized oil, is forced into the combustion chamber under the still higher pressure: the result is that its temperature, due to compression in an auxiliary cylinder prepared for that purpose, is already sufficient to ignite it explosively, and this result follows immediately it comes into contact with the oxygen of the air contained within the clearance of the cylinder. By the return stroke of the piston, the burned-out gases are entirely swept from the cylinder. While, according to authorities, the operation of the Diesel motor is very satisfactory in practice, the fact that it requires an auxiliary cylinder to compress the fuel gas to a very high degree effectually precludes its use for purposes such as motor vehicles, where all the available power is desirable for locomotion. It would also be quite impossible to operate it successfully without such pressure, or with fuel mixtures produced by any other form of carburetting device as above described.

Firing the Charge by Hot Head.—Another method of igniting the cylinder charge by hot walls and a temperature maintained by the act of compression is that used in connection with the Hornsby-Akroyd engine, already noticed. In this engine, the rear end of the cylinder is connected by a narrow passage with the closed chamber, whose general construction has been compared to a bottle or jug with a shortened neck; into this chamber also, at some convenient point, extends a vaporizing nozzle which is in connection with the source of liquid fuel supply. On starting the engine, the first act is to heat this hot chamber with a suitable torch, so as to bring it to the tempera-

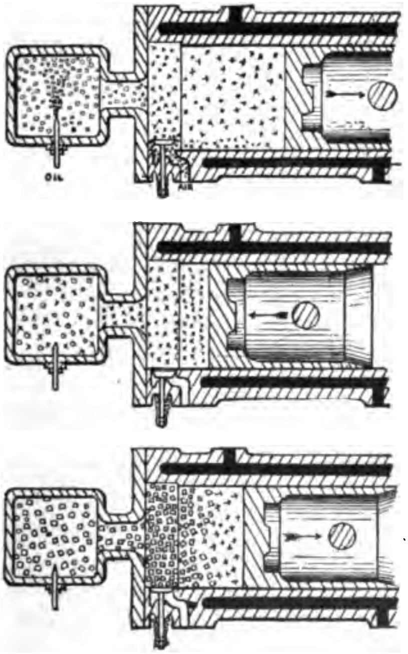


Fig. 178.—Diagram of the Hornsby-Akroyd Ignition System. At the end of the cylinder is a box, or chamber, connected to it by a narrow neck. During the suction stroke, shown in the first figure, air is drawn into the cylinder and oil sprayed into the hot igniting chamber.

ture required for exploding the charge. On the suction stroke of the piston, air is drawn into the combustion chamber of the cylinder through the ordinary poppet valve opening direct to atmosphere. At the same time, also, oil spray is forced through the atomizing nozzle directly into the hot chamber, where, although the temperature is fully sufficient to produce ignition, there is an insufficient quantity of oxygen to accomplish this result prematurely. The return stroke of the piston, compressing the air contained in the cylinder clearance to a very high degree, forces a certain portion of it through the narrow passage connecting with the hot chamber; and ignition immediately begins, the burning gases expanding and rushing into the cylinder during the succeeding out-stroke until the maximum volume is reached. After the engine has taken up its cycle, the temperature within the hot chamber is constantly maintained

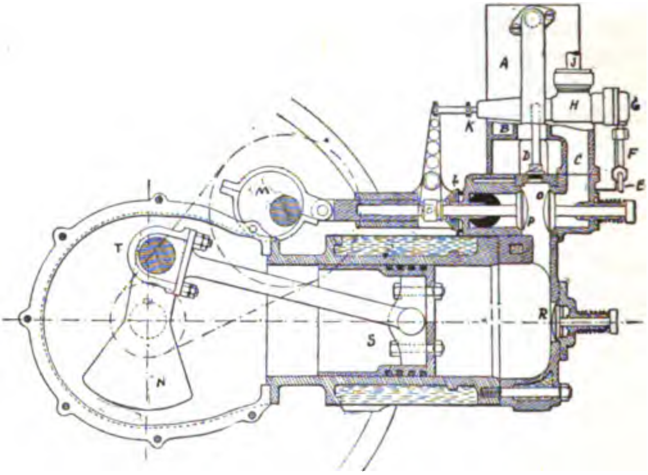


FIG. 179.—Roots' Kerosene Oil Motor for Vehicle Use. Sectional view showing the hot tube ignition, oil, vapor and air inlet and reciprocating parts. A is the vaporizing chamber surrounding the chimney of the hot tube, D. The eccentric, M, on the cam shaft actuates the exhaust valve, P, held in place by the spring, L, at the same time moving the link, K, which opens a valve contained in H, allowing a small amount of oil to be sprayed through the tubes, E, F, G, into the circulating chambers contained around the hot tube, D, as shown at B. The oil circulating around the heated space is transformed into vapor, which is fed into the channel, C, behind the inlet valve, O, which is opened by compression of its spring at the suction stroke. The valve, R, controlled by an adjustable compression spring, also admits sufficient air into the cylinder to give a mixture of the required proportion. The reciprocating parts are the piston, S, the connecting rod joined by a strap, T, to the crank pin, opposite to which is the balance weight, N. This section very well illustrates the workings of the type of explosive motor using hot tube ignition.

by the succession of explosive ignitions at high pressure, in precisely the same fashion as that already described in connection with the Diesel engine; the external source of heat being then, of course, withdrawn.

Firing the Charge by Incandescent Tube.—The hot head ignition system has been used very little, if at all, in connection with engines using mineral spirits as fuel. It is also a comparatively recent device, the earliest gas engines, as constructed by Otto and his collaborators, having a separately supplied and constantly burning gas flame, which was periodically connected with the combustion chamber of the cylinder by a peculiarly constructed slide-valve, the explosion of the charge being accomplished by a certain portion of the compressed mixture coming into contact with the flame. As a variation of and improvement on the above-mentioned device, the hot tube ignition was invented, the essential features of which are a tube of metal and porcelain, one end of which is connected direct with the combustion chamber, the other being closed. Around and against this tube the flame of a separately supplied gas burner is allowed to play, thus producing the required temperature for explosion. With some engines using hot tube ignition, the connection with the clyinder is controlled by a slide-valve in somewhat similar fashion to that used on the Otto engine, the valve being positively operated, so as to open and admit the compressed mixture into the hot tube at the proper point in the cycle. With others, there is no valve whatever, the act of compression alone operating to force the mixture into the tube and begin the process of ignition at or shortly before the end of the compression stroke. As may be understood, however, such an arrangement is liable to cause premature ignition under certain conditions, and is inferior to a well-geared device for timing the moment of ignition. Accordingly, a "timing valve," such as is shown in an accompanying figure, positively operated from the cam-shaft, has been used with some gas engines. In this device, the valve, *E*, is held open throughout the firing and exhaust strokes of the piston, so that it may be swept clean of the burned-out gases contained within it. Upon the completion of the exhaust stroke it is closed, and so remains until, at the predetermined point in the cycle, the push rod is again actuated from the cam-shaft.

Troubles with Hot-Tube Ignition.—In most gasoline vehicle engines using the hot-tube ignition, there is no provision, such as a geared timing valve of the general description noted above. Consequently, the hot tube opens direct into the combustion space of the cylinder—being closed from it at no time in the cycle. Some authorities have noted serious objections to the hot-tube ignition system, alleging that, under various conditions, it causes either premature ignition or missed fire, on account of the presence of burned-out gases within it. Under some conditions, it is stated, the tube is so filled from end to end with these residua that the charge in cylinder cannot come into contact with the incandescent walls, in order to ignite properly. Under other circumstances the tube is clogged with dead gases from its closed

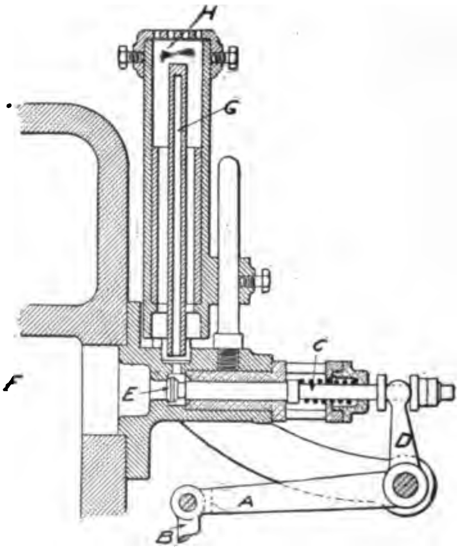


Fig. 180.—A Hot Tube Igniter, with a Geared Timing Attachment for Regulating the Point of Firing. G is the hot tube enclosed with a cylindrical case having a perforated cap, H, at the top. The heat of the tube is maintained by a gas flame within the cylindrical case. The link, B, operates the levers, A and D, so as to open the valve, E, which is normally held closed by the spring, C, bearing on its rod as shown. In opening the valve to the point in the cycle at which the cam actuates the link, B, thus compressing the spring, C, and opening the valve, D, the interior of the hot tube, G, is brought into communication with the combustion chamber, F, of the cylinder. The time of ignition may be varied by adjusting the throw of the cam, so as to bring the opening of the valve, E, to any desired point.

end nearly to the cylinder, and, when this condition is coupled with the fact that the heated portion is too near the entrance, premature ignition results before the completion of the compression stroke. Although these results may follow in a given type of engine, it is necessary to note several things: 1. The tube should be so constructed that the flame plays on that portion of its length which has been found to be at most suitable distance from the opening, not risking the danger of premature ignition, if it follows from such a cause only. 2. The tube should be heated to the proper temperature to secure the best and quickest ignition. 3. The temperature being properly arranged, the burned-out gases should be largely expelled from the tube by their own expansion under heat. 4. The compression ratio should be such that the fuel charge may be forced into the tube at the proper point, in spite of and against the expanding tendency of dead gases clogging its interior. With a well-made tube, a properly adjusted compression and a powerful jet flame, there is no reason for such accidents as are above mentioned. They result rather from faulty construction or bad management, and are not the necessary faults of the apparatus.

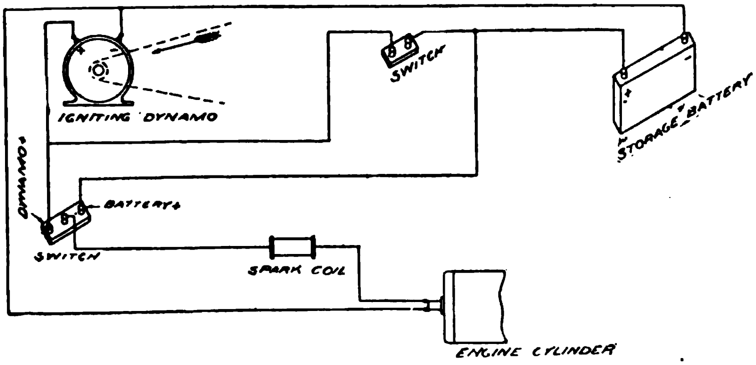
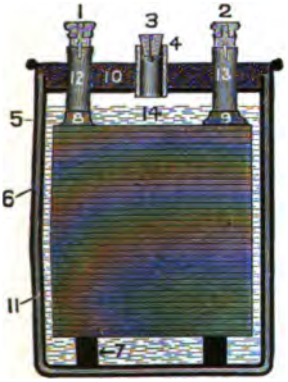


FIG. 181.—Diagram of a Primary Spark Circuit, equipped with a Dynamo and Storage Battery. The dynamo may be used to spark the engine and supply the battery at the same time, or to perform the former function exclusively. The battery is charged when the switch between it and the dynamo is thrown in. If the other switch is connected at the point marked "dynamo" in the cut. As is obvious from the cut, the dynamo may be cut out altogether, allowing the storage battery to supply current for sparking purposes. When both switches are in, the storage battery will supply current for sparking, until the dynamo has attained its full speed.

On Electrical Ignition Systems.—Although some effective types of automobile gasoline engines still use the hot-tube ignition, the larger majority are equipped with some form of electric-sparking device. This method has the advantage of providing an entirely intermittent source of ignition, and of being much more flexible than any constantly existing source of heat, such as found in hot walls or tubes, thus being susceptible of a nearly perfectly-timed ignition. The electric-sparking system, of course, requires some separate source of electrical energy, such as a battery of galvanic cell, a small dynamo, or a magneto-generator. The current thus generated is used to produce a spark, either from a primary or a secondary circuit; the former containing the ordinary reaction coil and producing a low-tension spark, from either a wiping or a breaking contact; the latter containing an induction coil and producing a high-tension spark between slightly separated terminal points. The latter variety is commonly known as the "jump-spark." The sparks of both varieties are successfully used in motor carriages, although the high-tension circuit and the jump spark seems to be the favorite.

Sources of Current: Chemical Cells.—The general plan with electrical ignition circuits, producing a spark from a secondary current, is to use some form of chemical dry-cell battery. Such chemical cells are necessarily of the open-circuit variety, since it would not be practicable to periodically interrupt the current from a closed circuit cell without using much more complicated machinery, and wasting an immense percentage of the total output. There are numerous open-circuit dry cells that are suitable for use in connection with the ignition circuits of gasoline vehicles; but it is not necessary to dwell upon their construction and properties, since the sole requirements seem to be reasonable durability and an average good output capacity; such cells rated from 1 to 1½ volts, are connected in batteries of three or four, so as to be capable of producing a current of the amperage required in any given case.

Storage Batteries.—With several makes of carriage, particularly such as are driven by high-powered motors, small storage cells are used as a source of current. The size most effective for this work is the 40 ampere-hour, which furnishes current sufficient, either for the continuous ignition of the motor or for starting, with a small dynamo or magneto, being then cut out by an automatic switch. As the general theory, construction and management of storage batteries are outlined in a later chapter, it will be necessary to say little here regarding them. The fact that a storage cell must be periodically charged from a source of direct current renders its use somewhat more troublesome than that of a primary cell. It has the great advantage, however, that, unlike any type of primary cell it may be renewed or recharged when the current gives out. When a direct current is available from street lighting or power mains, no switchboard or rotary converter is required for charging, as is necessary with the batteries used in propelling electric carriages.



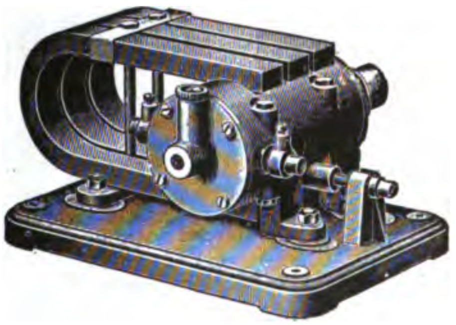


Fig. 182.—Section through a Type of American Storage Cell used for Gas Engine Ignition. The parts are: Positive binding post (1); negative binding post (2); rubber stopper (3); vent tube (4); outer metal case (5); lead lining (6); hard rubber insulator (7); positive element (8); negative element (9); sealing compound (10); hard rubber jar (11) positive terminal (12); negative terminal (13); the fluid or electroloyte (14).

Fig. 183.—Holtzer-Cabot Horizontal Magneto-Generator, used in the sparking circuits of gas engines. This machine is built on the same plan as the vertical magneto shown in Fig. 184; but to meet the requirements of many motor vehicle engines, is mounted as shown, in order to be more readily adopted to a limited space.

Magneto-Generators and Dynamos.—With gasoline vehicles using a primary sparking circuit, the source of electrical energy, except in starting, is practically always some form of small dynamo or magneto-generator. The primary distinction between these two forms of electrical source, as the words are generally used, is that the magneto-generator has a permanent magnetic field, being composed of several permanent magnets, in the field of which is a rotating shuttle-wound armature. The word dynamo, on the other hand, is commonly used to designate a mechanical source of electrical energy, having a separately excited magnetic field, consisting of an even number of pole pieces or cores, each of which is wound with a suitable length of insulated wire, connected in series to another length of opposed polarity throughout the entire circuit of the field. Between these pole pieces rotates an armature composed of a drum or a bar supporting a number of thin insulated metal discs, which are wound about with a suitable length of insulated wire, the two terminals being connected through the commutator to the outside circuit, which begins and ends at the commutator brushes. As the theory and construction of a dynamo are given later, they need not be treated here.

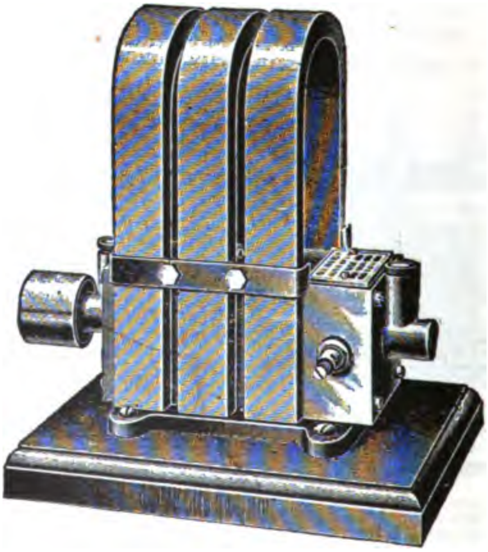


FIG. 184.—A Typical Magneto Generator—the Holtzer-Cabot Vertical Standard. The machine here shown is similar in all its details to the former, but is built in larger proportions and gives a more powerful output in E. M. F.

The Construction of a Magneto-Generator.—The commonest form of magneto-generator consists of two or more horseshoe magnets set in suitable pole pieces, between which rotates a shuttle-shaped armature wound about with a suitable length of fine insulated wire. As may be seen in the accompanying illustration, the lines of force extending between the poles of the magnets are variously distributed according to the point occupied by the armature in its rotation. It may thus be understood that any movement of the armature on its spindle, either in making a complete revolution or in oscillating backward and forward, must operate to deflect and distort these lines of force in such a manner as to set up powerful induced currents in the armature winding. Since, however, the paths of the magnetic forces are thus continually shifted from the lines of the least resistance to the lines of the greatest resistance, it follows that the current delivered from the terminal connections will have a constantly shifting potential, and will hence be an alternating current—that is to say, a current flowing first in one direction and then in another. This is the very thing that is required in telephone circuits,

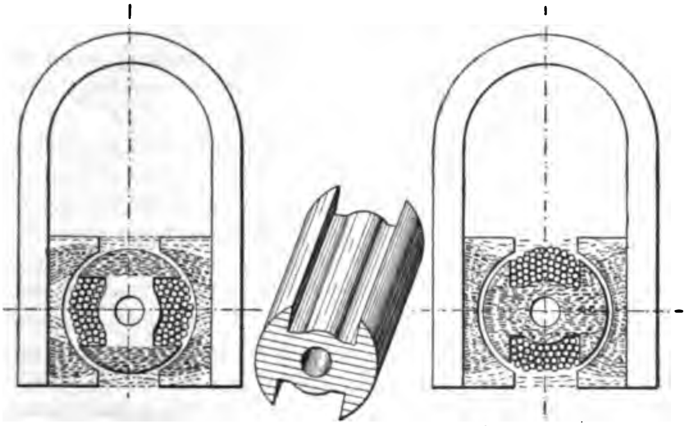


Fig. 185.—Diagram of the Construction and Theoretical Operation of a Typical Magneto-Generator. Between the prongs of the horsehoe magnets, the shuttle-shaped armature, shown at the centre of the figure, rotates on a suitable spindle. This armature is wound from end to end with insulated wire, so that when rotated a powerful current is produced in the windings by cutting the magnetic lines, whose varying strength is shown by the shaded portions in the two views. When the armature is in the position shown in the first diagram, the lines of force mostly converge at the top and bottom, finding a direct path through the metal and flanges of the shuttle. When in the position shown in the second diagram, the lines are converged so as to pass through the metallic core of the armature; the most direct path being chosen in both cases.

in which magneto-generators are commonly used to generate a current for operating the switchboard drops and transmitting call-bell signals. For this purpose, one end of the armature winding is connected to the centre of the rotating spindle, which is insulated; the other to the frame of the machine. Generators of precisely similar construction and wiring may be used for gas-engine ignition, provided the cut-off of the current be timed to occur at precisely the point of highest potential or greatest intensity, which is to say, when the longitudinal flange pieces of the shuttle-shaped armature are in a vertical position. For ordinary ignition circuits, however, the alternating current is not used, and consequently the magneto is equipped with a rotating commutator and terminal brushes, such as are used on direct-current dynamos.

The Operation of a Magneto-Generator.—The general operation of the magneto-generator depends upon a few obvious principles of construction, which we may sum up under the following heads: 1. The quantity of the current depends upon the strength of the magnetic field and the number of lines of force passing through the armature. 2. The electromotive force produced depends for its amount upon the length of the armature winding, and the rapidity with which the armature is rotated, cutting and deflecting the lines of magnetic force. If the armative be wound with comparatively thick wire, which would give a short winding, the E. M. F. will be low; but if it be wound with a finer wire, giving a much greater length, the E. M. F. will be higher, in ratio to the diameters of the wires used.

A Stationary Armature Magneto-Generator.—Although most of the magneto-generators manufactured for use in igniting gas engines conform to the general characteristics of the machines just described, an interesting variation is found in the Bosch & Simms stationary armature generator, which operates without a commutator, the terminals being connected to the outside circuit, as in the ordinary telephone magneto. The armature of this machine is shuttle-shaped and wound with insulated wire as already described, but it is fixed rigid at one end in such position that the lines of magnetic force strike directly through the insulated coil of the winding. The armature, however, is of somewhat smaller relative diameter than is used on the other types of magnetos, in order to leave a clearance for an intervening sleeve or open-sided cylinder of soft iron to be oscillated on the same axis between it and the pole pieces. This sleeve is caused to oscillate through about one-half a revolution by the connecting rod and crank geared to an adjustable cam on the secondary shaft of the engine, the difference in throw between the crank geared to the spindle of the sleeve and the radius of the cam operating to prevent a full revolution. This cam also operates to break the circuit at the contact points within the cylinder, at a predetermined point in the stroke, which is always made to occur at precisely the point when the oscillating sleeve is in position to cut through the greatest number of magnetic lines, thus producing the maximum E. M. F. The spark may be advanced by a feather on the cam, and a spiral groove cut on its spindle, so that when it is moved lengthwise the operation of the contact breaker may be varied, although maintaining the sparking point at the same maximum position of the oscillated sleeve. The positive terminal is on an insulated binding screw at the top of the armature, the path of the return current being through the metal of the engine cylinder, to the base of the magneto-generator. In general, the method adopted for driving the

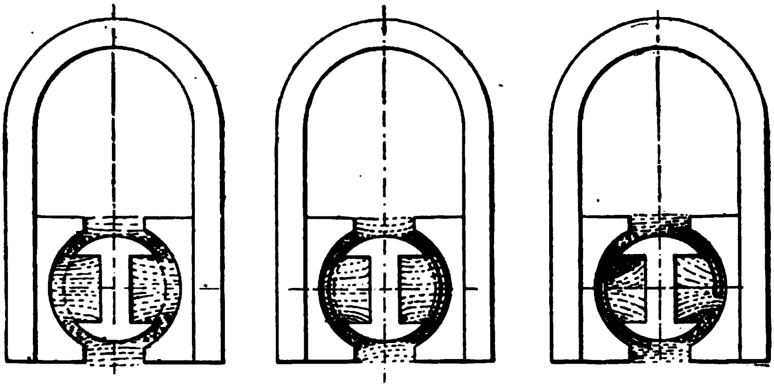


FIG. 188.—Diagram of the Construction and Operation of the Simms-Bosch Igniting Magneto. In this machine the armature is stationary, the lines being cut by an open sleeve rotating between it and the field pieces. The first diagram shows the convergence of the lines of force before the rotating sleeve has been inserted; the second shows the lines when the sleeve is directly across the magnetic lines; the third, where the sleeve is in position at oblique angles to the lines. As may be understood, this arrangement produces a very powerful variation of the field and a very strong output of E. M. F.

rotating portion of the magneto is to connect it direct to the flywheel of the engine, either by a belt or a brushing roller. With this arrangement it has usually been found that a current sufficient to begin sparking may be produced by the act of turning over the flywheel to start the motor.

The Primary Spark.—The primary spark is so called because it is produced on a primary circuit, as distinguished from one occurring on a secondary circuit, or a circuit in which a current is induced, as in an induction coil, by a make and break of the battery circuit, as will be subsequently explained. While it is possible to produce a small spark by simply breaking a battery circuit, it is necessary in order to have a spark of sufficient intensity and duration to introduce an effect of self-induction. This is done by passing the direct current—generally from a commutated magneto—through the winding of a long-wound magnetic, or reactance coil. The spark coil used in this method of ignition consists of a long iron core wound with a considerable length of

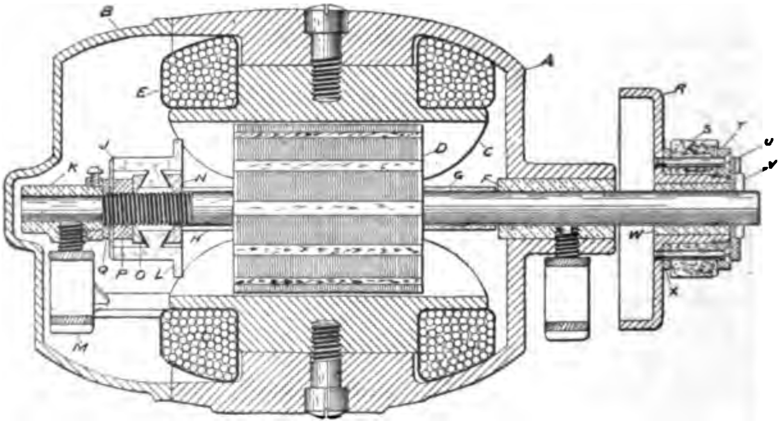


FIG. 187.—Sectional Diagram of the Apple Igniting Dynamo. The parts shown are: A, cast iron body containing the moving parts; B, the hinged lid of the body; C, the one-pole piece of the field magnets; D, the armature; E, the coil of one of the field magnets; F, brass bearing of the armature spindle; G and H, fibre tubes surrounding the spindle; K, brass spider supporting the spindle; L, commutator; M, wick feed oil cup; N, beveled nut supporting the commutator; O, P, Q, supports of the commutator; R, the driving disc; S, lever friction pinion. This machine can generate a direct current at 8 volts at a speed of between 1,000 and 1,200 revolutions per minute. It is provided with a simple centrifugal governor that automatically interrupts the driving connections when a certain speed has been exceeded.

low-resistance copper wire; the length of the core and the number of turns of the insulated winding determining the efficiency. The current passing through the winding magnetizes the iron, and a self-induced current is generated, which is occasioned by and superposed on the battery current. As soon as the circuit is broken, the magnetic reactance tends to continue the flow of current, despite the gap, and occasions a spark of great heat and brilliancy. The spark occurs at the moment of breaking the circuit, not at the moment of making With high speed engines a shorter core is used on the coil, the effect of a smaller magnetic lag being thus obtained.

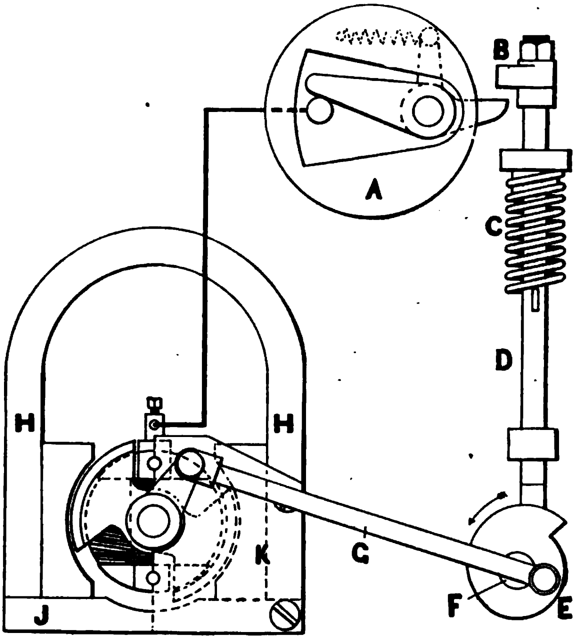


Fig. 188.—Diagram of the Simms Magneto and Primary Sparking Circuit. A is the metal base mounting the sparking contacts; B, a hammer head on rod, D, for actuating bell crank against tension of spring, separating electrodes; E, rotating notched cam on shaft, F; G, connecting rod for oscillating sleeve let over armature; H, H, magnets; K, pole piece; J, base plate of magnets.

Typical Means for Producing a Primary Spark.—There are two typical methods of producing a primary spark: (1) by wiping contact, in which one of the electrodes is constantly rotated, and (2) by breaking contact, in which one electrode is drawn away from the other at the proper moment for the spark. A common form of wiping-spark device is shown in an accompanying figure. Here the two electrodes, *X* and *Y*, the latter of which is set in an insulating plug, screwed into the wall of the combustion space, electrical connection being made by the wire shown at *D*. The electrode, *X*, is a rotating spindle, deriving it motion from the link and small crank shown at *E*, and forming the other terminal of the circuit, through the wire connected to the nut, *M*. On the end of the terminal, *Y*, is a resilient spring of platinum, which forms a contact with the electrode, *X*, and enables a spark to be formed whenever the contact is broken by its rotation. This method of periodically breaking the contact is so varied in several types of gas engine that the simple make-and-break device,

FIG. 189.—Details of a Common Form of Contact for Producing a Wiping Spark. The electrode, X, rotated by the crank, E, as indicated, gives a wiping contact and break at the terminal, Y, which is tipped by a resiliant platinum spring. One of the wires forming the circuit is connected at D through the insulated plug screwed into the body of the ignition chamber; the other is connected to the metal of the chamber at the nut, M. The advantage of this form of sparking device is that the constant contact of the electrode keeps the surfaces clean, but at the same time the constant friction produces an immense wear for the same reason. An excellent form of simple make-and-break device is shown in connection with the suction of the Duryea cylinder in a succeeding chapter.

FIG. 190.—The Apple Magnetic Ignition Plug for Producing a Primary Spark. The two electrodes, as shown, are normally in contact, the coil contained within the cylindrical shell of the plug acting as a magnet to break the contact at the required point. As claimed by the manufacturers, the advantages of this device are ready adjustment and repair, a ready cleansing of the contacts, and the avoidance of any other coil than is used within the plug itself. The spark can also be controlled from the outside, the same as with the jump-spark coil, with the combined advantage of much greater simplicity of parts and circuit arrangements.

positively operated, is substituted for the wiping contact of the rotating electrode. The advantages of the wiping contact are that the surfaces of the electrodes are constantly wiped clean of any impurities produced by the combustion of the fuel charge in the cylinder. It has, however, an even greater disadvantage involved in the enormous wear of the small points due to constant friction. The simpler make-and-break device, on the other hand, while producing quite as good a spark, permits no really reliable method of preventing the deposit of carbonized particles, which weaken and eventually choke the spark.

The most widely famous primary ignition systems are those used on the early Mors carriage motors and the Simms & Bosch system, already noticed. Among the best known makes of American gasoline carriage motors using the primary spark may be mentioned the Duryea and Haynes-Apperson.

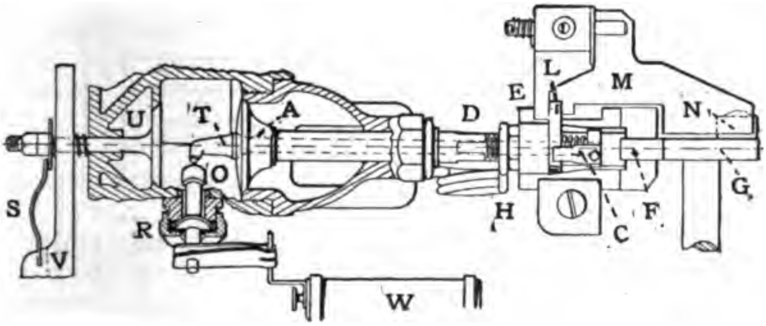


FIG. 191.—The Duryea Primary Spark Ignition Apparatus. A is the exhaust valve; D, the exhaust valve stem; T, the stem of the sparker hammer, journaled in the stem, D; E, the exhaust slide; F, roller at end of E; G, the rotating exhaust cam; H, exhaust valve spring; J, a clamp fixed in position by a set screw; M, pivoted lift that trips the hammer, L, operated by roller, N, beside the exhaust cam, knocking the sparker, T, away from the insulated plug, O. U is the inlet valve; V, the throttle slide; S, spring controlling the opening of U; W, the spark coil; R, the metal union nut, clamping O in place.

The Duryea make-and-break apparatus closely resembles the Mors. The current is carried to the engine by a bare wire attached to an insulated stem by a spring clip, which is caused by vibration to grip tighter, thus insuring a constant contact. Around the middle of this insulated stem is a flange, on both sides of which ordinary mica washers are placed. A metal union nut or cap binds the mica washers and the stem to the base of the plug, which in turn screws into the cylinder wall, allowing the end of the plug to project inside. This end is tipped with a ring of nickel alloy, which resist both heat and corrosion better than other metals, and can be turned around when worn. The mica insulation is not exposed to soot, oil and burned gases, and keeps clean for hundreds or even thousands of miles. The union nut or cap can be unscrewed quickly, exposing the mica and permitting the dirty one to be removed. Through the hollow exhaust valve stem a sparker stem is inserted having conical ground joints in the exhaust valve seat, and with bent point or arm nickel tipped and adapted to contact against the insulated nickel ring. The projecting outer end of this sparker stem is provided with a hammer spring and clamp, the latter being held by a set screw firmly on the stem. A flat lift raised by a roller on the exhaust cam, raises the hammer and permits it to drop suddenly under the action of the spring, causing it to strike the clamp and knock

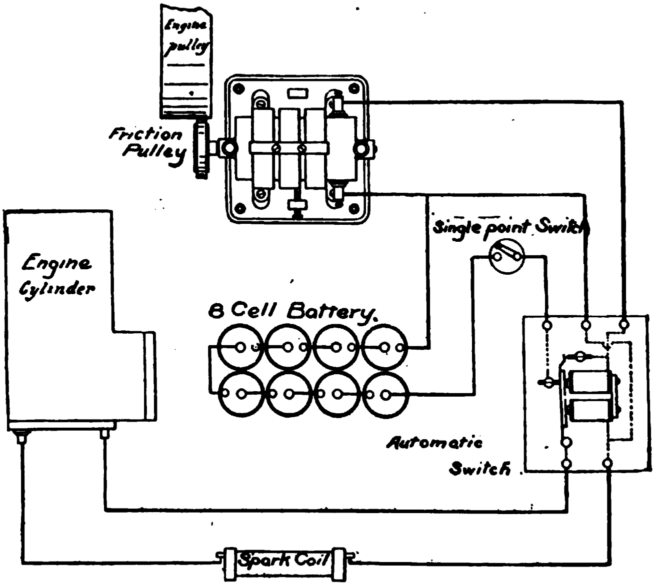


FIG. 192.—A Primary Spark Ignition Circuit, containing a magneto-generator, an 8-cell chemical battery, and an automatic cut-off or relay. The chemical battery is used to supply the current for producing the spark until the magneto-generator has attained its required speed. At that point the current from the generator passing through the coil of the automatic switch is sufficiently strong to cause the magnets of the relay to attract their armature and cut the circuit of the chemical battery. This circuit may also be cut out at any time desired with the single point hand switch.

the sparker point out of the engagement until the lift is again operated. The exhaust cam pushes the exhaust valve with the sparker parts out of the way, so that the lift may return to its original position, ready to repeat the operation. This mechanism is quite simple and is located on top of the motor in a most accessible position.

With every variety of primary sparking circuit the most available means for timing—advancing or retarding—the spark is some device for rotating the throw of the actuating cam through part of a revolution in the one direction or the other. This may be done by placing the cam on a sleeve, to which a twist may be imparted, either from a centrifugal governor or by a hand-operated gear. Advocates of the primary spark claim that it is quite as reliable and serviceable for ignition as the secondary or jump spark, while not requiring the complication of an induction coil, condenser and trembler, and doing away entirely with the troubles involved in the use of plugs. It is, however, less flexible, as ordinarily produced, and so has been discarded for the high-tension apparatus by the majority of high-powered carriage builders.

Properties of the Jump-Spark.—With the jump-spark produced from a secondary circuit, there are no movements of the electrodes, the primary circuit being periodically broken by a positively operated circuit-breaker, which thus induces an intermittent current of varying intensity in the secondary. The electrodes are usually contained in a device known as a sparking-plug, in which they are insulated from one another, by the use of porcelain, mica or other suitable substance. The most common objection to the use of the jump-spark is found in the fact that particles of carbon dust, produced by the combustion of the fuel charge, are deposited between the small sparking points, thus preventing the formation of a spark, by filling up the gap, across which the current is obliged to leap in forming the spark.

In order to obtain a secondary current with the use of a chemical battery or direct current mechanical generator, it is necessary to interrupt the primary circuit at timed intervals. There are two methods by which this is accomplished: (1) by the use of a snap cam that once in every revolution brings together the terminals of the circuit; (2) by the use of a wipe-contact interrupter, or "commutator," and a magnetic trembler at one pole of the coil core. Only a very rudimentary knowledge of electrical apparatus is required to make it evident that snap cam and trembler cannot be advantageously used in the same circuit. The two varieties of apparatus are very well shown by the two typical circuits, the De Dion and Benz. Both of them also illustrate the prevailing method of grounding the negative lead of the secondary circuit to the metal of the engine. The general principles are explained with single cylinders, but multiple cylinder arrangements are shown later.

The De Dion & Bouton Jump-Spark Circuit.—Very nearly the typical arrangement for the high-tension jump-spark circuit is that used on the De Dion & Bouton carriages. The general plan of the connections is shown in an accompanying diagram, where, as may be seen, the current produced by a chemical battery is passed through the primary winding of the induction coil, the circuit being periodically broken by a vibrating trembler or contact breaker, the details of which are also given. The positive pole of the battery is connected to the primary winding of the induction coil, the opposite terminal of which is connected to the lower of the two binding screws attached to the vulcanite base of the contact breaker. The negative pole is grounded to the frame of the carriage and thence the metal of the motor cylinder, the circuit being completed by a wire connecting with the upper binding post on the contact breaker. The operation of this contact breaker is obvious. It consists of a positively operated cam on the two to one shaft, of round contour except for an irregular sector-shaped notch in its circumference, which allows the point of the trembler, *T*, to drop when the notch meets it in the rotation of the cam, thus making contact from the terminal, *B*, and the upper binding post on the base of the apparatus, with the negative pole of the battery, and the screw, *d*, which is connected through the lower binding post with the positive pole of the battery, as already explained. By this means, the circuit being periodically broken, a powerful high-tension current is produced in the secondary winding of the induction coil, one terminal of which is connected with the insulated portion of the sparking plug, the other with the metal of the cylinder; the spark being produced between the terminal contacts of the plug at every interruption. By this arrangement of the circuit the

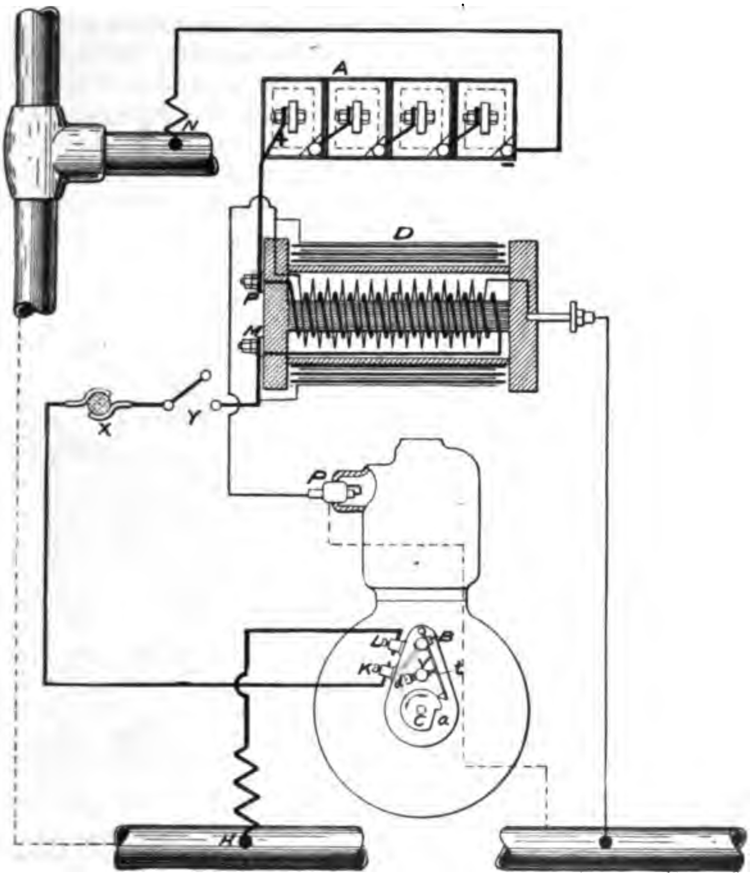
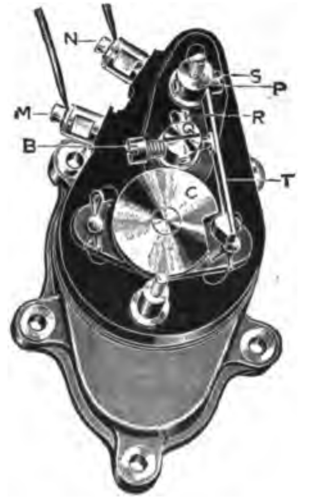


Fig. 193.—Diagram of the De Dion Jump-Spark Ignition Circuit. A is a battery of four cells, one pole of which is connected, as shown, to the tubular frame of the carriage at the point, N, the circuit being thus completed through the steel frame work to binding post, L, on the circuit breaker; thus, the circuit is made by the contact of the trembler, T, with the point of the screw, D, on the post, V, through binding post, K to M, thus through the primary winding of the induction coil and to the oposite pole of the batery. The secondary circuit joined by one pole of the condenser, D, is connected to one end of the sparking plug, P, the other, being grounded to the frame, completes the circuit by the metallic contacts with the body of the motor, as indicated by the dotted line.

electrical potential of the secondary circuit, and therefore of the grounded point of the sparking plug, are reduced to the lowest value, the negative terminal of the battery affording a constant dead ground at a much lower potential than may even be found in the metal base of the machine as a whole. On the closing of the primary circuit through the contact spring, as already described, the current in the primary winding of the induction coil rises rapidly to its full value against the opposing self-induced current generated in the coil, and establishing a powerful magnetic field, whose lines of force intersect the plane of the convolutions in the secondary circuit, creates therein, during the brief period when the battery current is flowing, a constantly increasing difference of electrical pressure between the grounded secondary terminal and the opposed extremity of the same winding. The difference of electrical pressure, resulting from the increasing density of the magnetic field, is not great enough, however, to cause a spark discharge between the points of the plug, owing



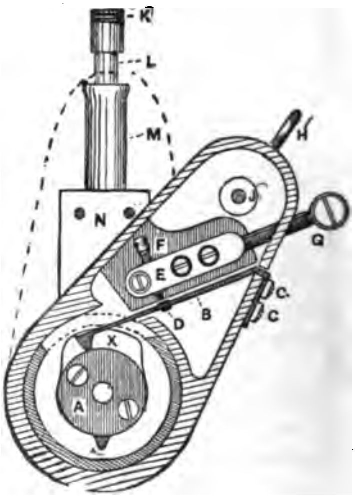
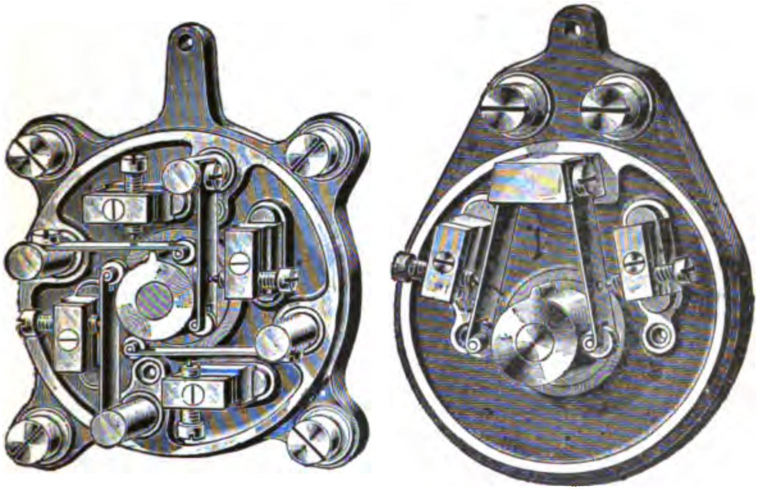


FIG. 194.—The De Dion & Bouton Single Cylinder Circuit Breaker. B, platinum-ended screw; C, notched cam; M, terminal in contact with B and Q; N, wire terminal in contact with P, S and T; P, stud supporting the trembler; Q, split projecting stud supporting the platinum-tipped screw, B; R, screw to make Q grip B; K, screw fastening trembler, T, to base, P; T, the trembler spring.

FIG. 195.—Contact Breaker of the Minerva Single-Cylinder Tricycle. A, rotating cap on end of secondary shaft, carrying point to left trembler, B; X, cam to lift valve stem; C, C, screws connecting trembler spring to frame; D, stud of platinum making contact with tip of E; F, mica sheet; G, brass screw holding one end of the circuit wire; K, exhaust valve lift; L, stem sliding inside of tube, M, secured to plate, N; H, ring for holding wire screwed at G; J, pivot for rod moving contact breaker through arc from position shown to that indicated by dotted outlines.

to the fact that the range of change in the density of the magnetic field is retarded by the self-induction of the primary circuit opposing the rapid flow of the battery current. A condenser is therefore used, one pole of which is connected to the primary terminal, wired to the lower binding post of the contact breaker and thus to the screw, *D,* already mentioned, the other being connected to the grounded terminal of the secondary circuit. By this means the magnetic field produced in the primary winding of the coil is almost instantly destroyed whenever the battery circuit is broken. Thus, it is possible to obtain a high-speed rate in alternately making and breaking the primary circuit, while at the same time maintaining a secondary current of sufficient potential to produce a powerful spark without interference from the self-induced current produced in the primary winding of the coil. The action of the condenser is virtually "a heaping up of electrical pressure at the end of the wire of the primary circuit, to which it is attached." This, discharging through the only available outlet, sweeps back through the primary coil and instantly



FIGS. 196 and 197.—Contact Breakers for Two and Four-Cylinder Engines of the general type resembling that shown in the last figure. As may be seen, the springs are brought into contact with the anvils representing the terminals of the circuit, as the projecting point on the sleeve rotates so as to engage each roller in turn. Such apparatus are used in circuits having no tremblers on the coils.

demagnetizes the core, owing to the fact that its flow is in the reverse direction to that of the original self-induced current. This effect is produced with great rapidity, and is a potent factor in rendering the De Dion system one of the simplest by which a high-tension current may be generated for ignition purposes. Among the objections to the system may be mentioned the fact that a large primary current is required in proportion to the useful work accomplished, which contributes to the end of speedily exhausting the battery.

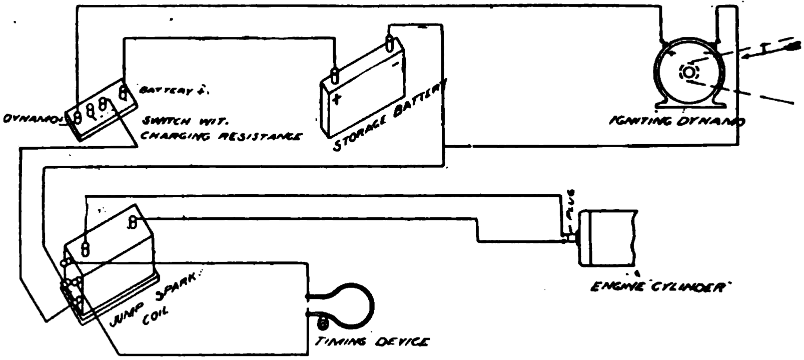


FIG. 198.—Ignition Circuit, containing a Dynamo Generator and Storage Battery. Both terminals of the secondary winding of the induction coil have visible leads to the sparking plug. An adjustable vibrator on the coil enables the timing of the spark. As in Fig. 329, the storage battery furnishes current for sparking until the dynamo has taken up its speed, and may then be cut out of circuit, as desired.

The Benz Jump-Spark Circuit.—The constructional and operative objections involved in the De Dion ignition circuit are largely overcome in the Benz, which embodies many of the features most often used with modern gasoline engines employing this method of ignition. Instead of the notched cam and trembler spring used on the De Dion motor for periodically breaking the circuit, a leaf spring, carrying a contact button at its free point, bears against the circumference of a rotating vulcanite disc, which through a small arc carries a brass plate electrically connected to the spindle of the rotating disc. This spindle forms one terminal of the induction coil primary. The spring bearing upon the periphery of the rotating disc is connected direct to the negative pole of the battery. By this means, whenever the brass plate on the disc comes in contact with the button carried at the extremity of the spring, the primary circuit is formed.

The induction coil used with this ignition system is of the usual construction, except that it has a magnetically operated contact breaker, which serves to break the primary circuit as soon as the core has acquired its full magnetic properties. The current, emerging from the positive pole of the battery, moves along wire, *A*, to binding-post, A^1, and thence to the screw *B*, which is nor-

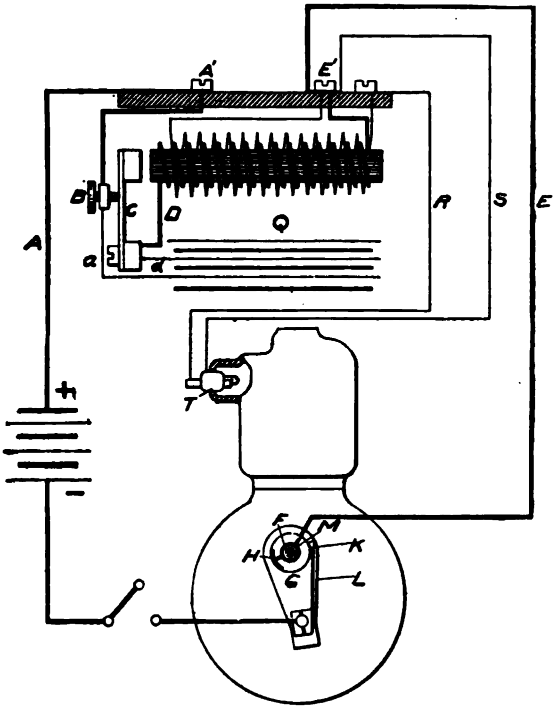


Fig. 199.—The Benz Jump-Spark Circuit. Unlike the De Dion system just described, both the primary and secondary circuits are carried by visible leads, no part of either being grounded to the frame. The circuit emerging from the positive pole of the battery passes through wire, A, to binding post, A' on the coil, to one contact at B of the trembler, C, thence through C and D to the primary winding of the coil; then through *a* and *d* through the condenser, Q. The other terminal of the primary winding emerges from binding post, E', passing over lead wire, E, to sleeve, M, of the rotary cam, G. The sleeve, M, is in electrical contact with the metallic section, H, on the circumference of the cam, being turned on the spindle, F, so as to periodically make contact with the head, K, of the trembler spring, L. The secondary circuit is completed through lead wires, R and S, to the two terminals of the plug, T.

mally in contact with spring, *C*, of the contact breaker. Moving through the spring, it emerges on wire, *D*, thence through the primary winding of the induction coil to binding-post, E^1, and wire, *E*, which is in electrical contact with the spindle, *F*, of the rotating disc, *G*. The circuit is closed, as already stated, whenever the brass arc, *H*, on the periphery of the disc is brought into contact with the button, *K*, carried on the spring, *L*. The point of ignition may be timed by modifying the relative positions of the contact piece, *H*, and the button, *K*; this act being accomplished by loosening the adjustment screw and turning the disc,

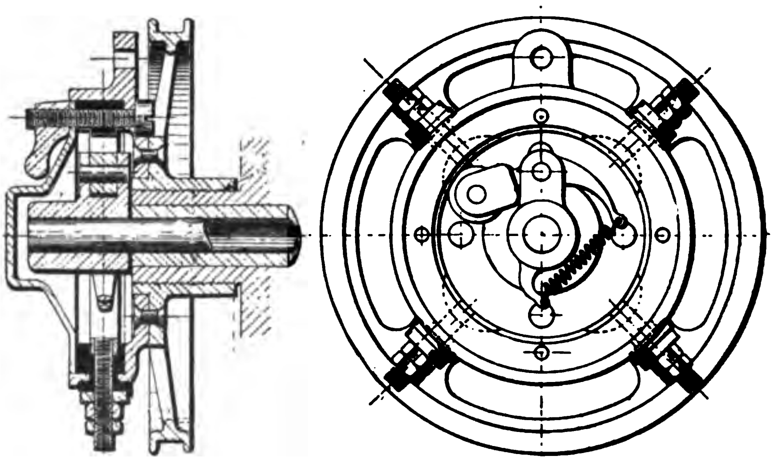
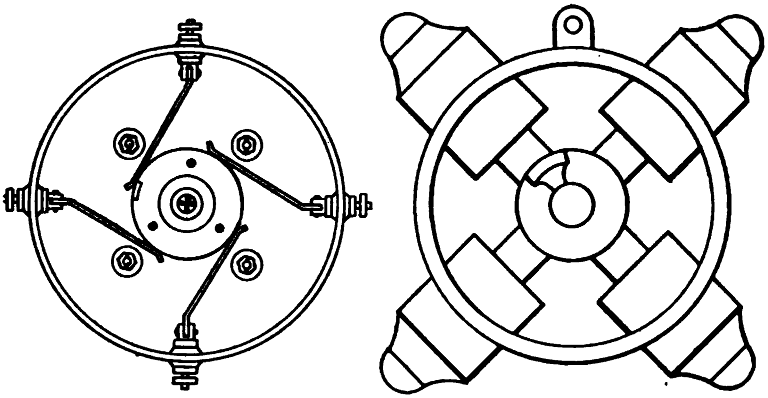


Fig. 200.—Type of French Wire-Contact Circuit Interrupter used on Circuits having Magnetic Tremblers on the Coils. As shown, the roller comes into contact with the arc-shaped plates representing terminals of each of the four coil and plug circuits, making each of them in succession.

G, on the spindle, *F*, to the required point. The metal sleeve, *M*, in contact with the spindle, *F*, maintains the electrical contact between, *H* and *F*, and thus with the wire, *E*, no matter what may be the degree at which the contact, *H*, is shifted. The spindle, *F*, being a secondary shaft, rotates so long as the engine is in motion, thus making the primary circuit once in every two revolutions of the flywheel.

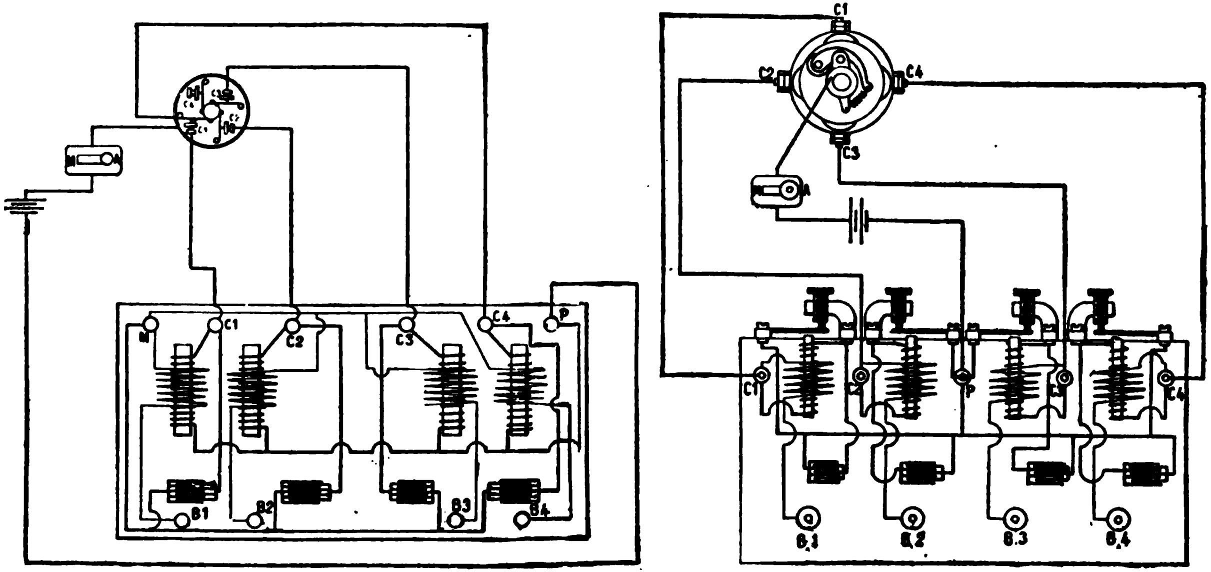
The two terminals, *B* and *C*, of the wires, *A* and *D*, are connected as shown by the wires, *a* and *d*, with the condenser, *Q*, the object being, as with the De Dion system, "to suppress the spark discharge of the primary self-induced current, which otherwise would take place on the break of circuit, and to increase the rate of demagnetization of the core."

As may be readily understood, the primary circuit has scarcely been made before the iron head of the contact breaker, carried on the spring, *C*, is attracted to the core of the induction coil, thus momentarily stopping the flow of current. Its vibrations, however, are of great rapidity, averaging at least four complete breaks during the brief period in which the brass piece, *H*, on disc, *G*, and the button, *K*, on spring, *L*, are in contact. The result of these rapid fluctuations of the magnetic field is a continuous stream of hot, flaming sparks between the points of the plug, during the period in which the primary circuit is made, the number of impulses of the secondary current on the wires, *R* and *S*, to the two terminals of the sparking plug, *T*, being greatly increased.



FIGS. 201 and 202.—The Rotating Insulated Disc and Spring Commutator of the Locomobile Gasoline Engine. The rotating wipe contact of the Peerless engine. Each of the four cylinders is ignited in succession as the contact is made by the rotating grounded member. Tremblers used on the coils.

Timing the Spark.—With neither of the systems as described is there any provision, except adjusting the cam, for advancing or retarding the time of the spark—which is to say, making the closure of the primary circuit at a point shortly before or shortly



FIGS. 203 and 204.—Diagrams of Four-Cylinder Sparking Circuits, the first using a drop cam contact breaker without magnetic tremblers on the coils; the second, a wipe-contact interrupter with tremblers. In these figures, A and M are the off and on positions of the switch; C^1, C^2, C^3, C^4, the primary terminals of the coils; P, the opposite pole of the batery; M, the point of grounding the secondaries; B^1, B^2, B^3, B^4, the plugs. Details of circuits as in the typical circuits already described.

after the completion of the compression stroke. By advancing the spark a longer period of expansion, consequently a greater economy of effective power, is obtained: by retarding it the expansion is shortened, and the power effect is not as great. The best efficiency is obtained when the piston moves outward under full power impulse from the very start, which is possible when the gas mixture is in a state of complete ignition.

The control of the spark could be constantly in the driver's hand with such motors as have been just described, if the cam or the commutator were set on a sleeve, arranged, as in the Simms system, to be shifted around through part of a revolution, thus making the spark occur at an earlier or a later moment, or if the base holding the binding screws and contact spring were arranged to move through a short arc around the secondary shaft. Such an arrangement has actually been applied on a single cylinder bicycle motor, with which a snap cam contact breaker is used.

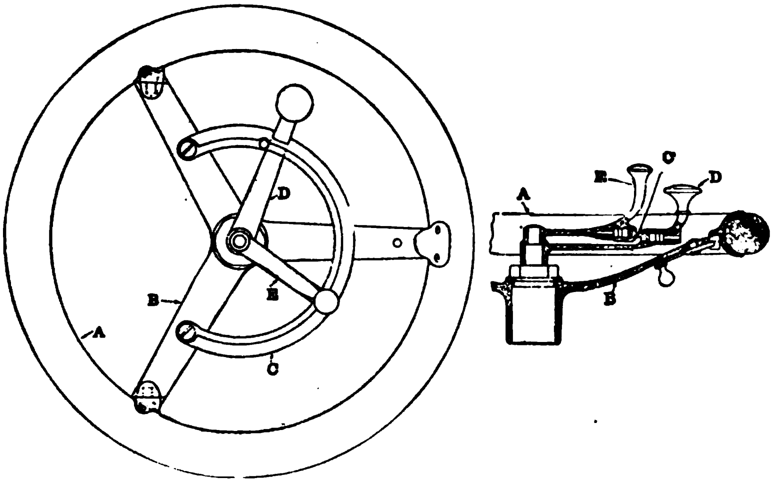


Fig. 205.—Steering Wheel and Attachments of the Pope-Toledo Carriage. A is the wheel rim; B, a spoke or arm of the three-armed spider; C, sector for sliding arms, D and E; D, throttling arm and handle; E, spark regulating handle.

With multiple cylinder engines very similar devices are used for periodically making the circuit. With many of the best makes of carriage the coil is furnished with a magnetic trembler and the primary circuit is made and broken by a rotating wipe contact commutator. As shown in accompanying figures, the rotating member may be either an insulated disc with a single conducting contact, as in the Benz jump-spark circuit, or a contact piece bearing on an internal insulated track with conducting surfaces corresponding to the number of cylinders to the fired and to the disposition of their cranks in degrees. With such devices the spark may be timed, either by turning the frame through part of a revolution, or by turning the sleeve carrying the rotating member. Precisely similar apparatus are made to operate with snap cams, as shown in the figures. Several carriage motors have the spark timed by automatic action, as shown in the cut of the Riker-Locomobile governor in a later chapter. With others it is done solely by the action of the driver. Although, of course, in every case, the advance or retardation can extend through a very limited arc, strictly within the limits of safe firing.

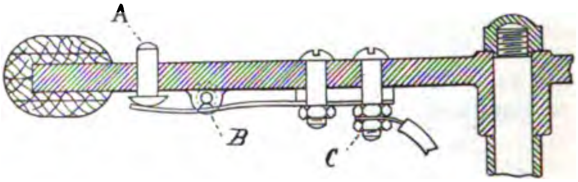


FIG. 206.—The Searchmont Steering Wheel with Electric Circuit Breaker One terminal is at C, the other at pin, B. By depressing button, A contact may be broken. By withdrawing pin, B, circuit may be interrupted, rendering it impossible to start the engine.

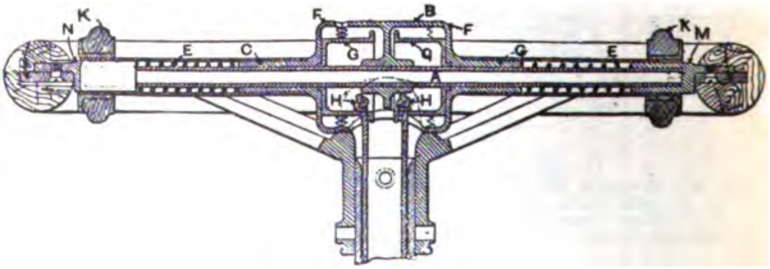


FIG. 207.—Steering Wheel and Attachments of the Panhard-Levassor Carriage. A, a shaft on a diameter of the wheel; B, a cylindrical fixed cap with toothed ends; C, C, a sleeve with toothed ends, F, F, in normal engagement with B, under tension of springs, E, E, being prevented from rotating; G, G, drums on which wire cables, H, H, are secured and wound; K, K, knurled handles, which may be grasped and pulled against the springs, allowing rotation of G, G. One cable, H, leads to carburetter link, the other to the spark adjuster.

The Outside Spark-Gap.—By a form of device recently introduced, the short-circuiting, due to fouling and carbonizing deposits between the points of a high-tension spark plug, is effectually overcome. Since fully 60 per cent. of motor troubles with this variety of spark arise from short circuiting, the value of the device must be apparent, and it is fairly evident that automobile operation in the future will be a far less troublesome pastime than was possible in the past. Briefly described, the auxiliary spark gap, as it is called, is a form of condenser, or capacity, in which the air acts as the dielectric between two surfaces, set at the terminals of a gap in a high tension circuit.

FIG. 208.—Outside Spark Gap in the form of Chains, as applied on the Riker-Locomobile engine.

The conditions that enable the production of a spark-discharge between the two terminals of the gap in such a circuit involve simply that an electrical charge be accumulated on one terminal surface, until the high pressure breaks down the dielectrical resistance of the air, and enables the spark to jump across. The result is, of course, that the electrical impulses are very greatly intensified, and become capable of exerting many times the effect otherwise to be obtained. This principle is proved true in the case of high-tension spark plugs, which, although so befouled and short-circuited as to miss sparking with a current of ordinary pressure, operate quite as well as perfectly new and clean plugs, when the outside gap is placed in the secondary circuit. The reason for this is that, the pressure having been raised to many times the normal secondary voltage, the oscillating current, moving swiftly, is able to arc across between the metal points, avoiding the high-resistance path through the short-circuiting deposit of carbon and oil residuum, in precisely the same fashion that lightning leaps to a conductor. Interesting experiments have been tried to demonstrate the ability of an outside spark-gap to produce a spark in the motor cylinder, even when it was impossible to use the plug without it, and even when an excess of lubricating oil, deliberately poured into the combustion chamber, quickly produced fouling between the points.

FIG. 209.—One form of Outside Spark Gap.

Operative Advantages of the Spark-Gap.—Other advantages of the spark-gap are that it furnishes a sure indication of the conditions of operation—always sparkling when the plug sparks within the cylinder, and failing to spark when any disarrangement in the outside circuit has interrupted the operation of the battery. The time of the spark may also be accurately determined and regulated to suit requirements; the fact of its adjustment being always surely indicated to the eye. It further allows the secondary current to reach its full tension, by eliminating the leak formed by the deposit of soot between the terminal points of the plug. As a consequence, also, the movement of the vibrator on the spark coil becomes noticeably slower, greatly to the advantage of the battery, whose life, according to some authorities, is even doubled. This result follows, since the accumulations of energy periodically taking place at the terminals of the gap allow sufficient time for more complete magnetizations and demagnetizations of the core, with the result that the primary current reaches its maximum more slowly—the secondary being unable to discharge with the same rapidity as when no gap is used. According to the claims of some authorities, it is possible with the use of a well-designed spark-gap to spark successfully, even with faulty insulation in the secondary circuit, such as would entirely prevent ignition under ordinary circumstances.

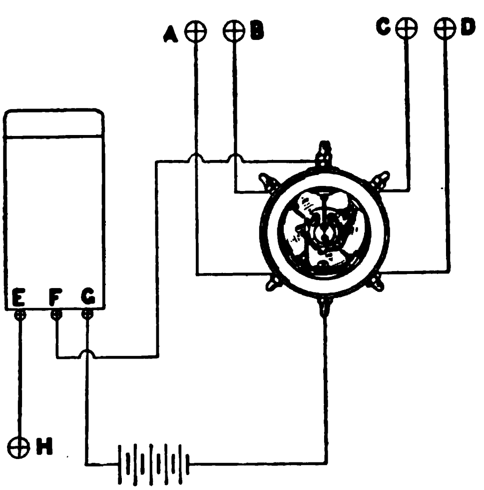


FIG. 210.—The King Automatic Spark-timing Device. It consists essentially of a rotating member, deriving its movement from the secondary shaft of the engine, and automatically regulated with relation to the four spark plug terminals by a spring governor mechanism. Between this rotating member and each terminal is a gap, an auxiliary spark gap. A, B, C, D, are the plugs; E, the primary and secondary lead from the single coil grounded to the engine at H; F, the secondary positive lead; G, the primary positive lead.

Design and Adjustment of Spark-Gaps.—Among the important points touching the design and operation of spark-gaps may be mentioned those concerning the distance apart of the charging points, the shape of the points, and on the question of maintaining the resistance of the air-dielectric. The space between the sparking points varies between 1-32 inch and 1/8 inch, according to the requirements in hand, which can often be best determined by experiment and adjustment. As a general rule, the further apart the points are fixed—of course, within the limits named—the better the effect; since, by thus obtaining a higher resistance in the intervening dielectric, the pressure in the secondary circuit is enabled to rise to its maximum strength, before a discharge can occur. The result is a spark of far higher calorific value. According to general directions furnished by manufacturers, the adjustment of distance between the points of a spark-gap should be made while the engine is in operation. The best results may, then, be accurately determined.

In addition to obtaining a sufficient distance between the point to secure the required dielectric resistance, some authorities claim that air should be allowed to circulate freely in the instrument, thus preventing the lowering of resistance due to heating. This, however, seems to be contrary to the practice followed in some of the most successful types of the apparatus, which are made with a case enclosing the points quite completely, and providing a glass top for the purpose of enabling observation by the driver. With 3/8 inch space between the points the resistance of the air seems to be sufficient under all conditions for the common requirement of most motors.

The Shape of the Gap Terminals.—Many makers of these instruments point the terminals, others claim that this is an error, since points allow the current to slip over the air gap in a fine brushlike stream, thus effectively lowering the voltage, and interfering with the prime requirement in the gap, "to dam up the current until there is a sufficiently large pressure stored at the terminal to overcome the dielectric resistance, and jump across in a lump." While pointed terminals operate moderately well, particularly when a sufficient gap is arranged between them, the criticism here made is supported by the common practice in other branches of electrical industry, in which high-tension sparks are used—ball terminals being the nearly invariable rule. In the new Riker gasoline cars the spark gap takes the form of a chain, which also serves as a flexible attachment for the conductors. The sparks leap across such gaps as occur between the links, thus apparently accomplishing quite as good security for perfect plug operation, as found with other types.

Wiring a Spark-Gap.—In wiring the spark-gap it is necessary only to open the secondary circuit and insert the device. If it is to be mounted on the dash board, heavily insulated cable must be used, as the high tension current is liable to short-circuit with ordinary bell-wire coverings. In general, long reaches of wire should be avoided as much as possible, and, if used, should be of low resistance. Occasionally, in such cases it is necessary to use some form of compensator.

Fig. 211.—"American" Indestructible Sparking Plug. This plug has two essential parts—the shell carrying one electrode, which screws into the metal of the cylinder, and the core composed of mica, through which runs the other terminal, the two being joined together by screw connections as shown. The superior advantages of mica insulation, as claimed by the manufacturers, are that heat has no effect whatever upon it; thus rendering it much more durable than a plug made of porcelain or other substance liable to be affected by heat and allow short-circuiting of the sparking current.

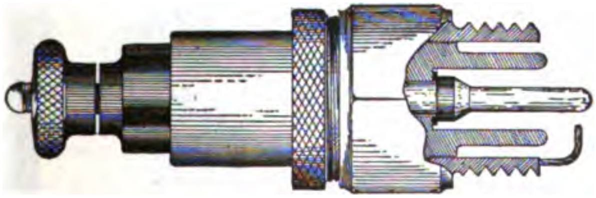


Fig. 212.—Part Sectional View of the Mezger Porcelain Spark Plug. Like the plug just shown, the shell of the plug is in two parts—one screwing into the wall of the cylinder, the other into the first. The porcelain insulating core is held between them by a shoulder. The insulated electrode rod is let through a perforation in the porcelain, having a shoulder to bear against it at one end, as seen, and being threaded to receive a retaining nut at the other. Ample air spaces are shown between the porcelain and the two terminals of the circuit.

Points on Sparking Plugs.—As previously stated, the plugs used for sparking on high-tension circuits consist essentially of two terminal electrodes separated by an air gap of such length as to permit a spark to arc across at the given tension of the secondary circuit. These two electrodes must be in contact at no other point, nor, if we are to have a spark sufficient to ignite the fuel charge in cylinder must the insulation be imperfect at any point along the leads, so as to admit of short-circuiting or leaking. From a theoretical point of view the problem is a simple one, since there are many dielectrics whose resistance is so immense as to render them very nearly absolute insulators. Practically, however, there are a number of considerations that enter to render the construction and operation of sparking plugs a matter by no means simple. In the first place, the very high temperature within the combustion space of a gas engine is liable to so affect many

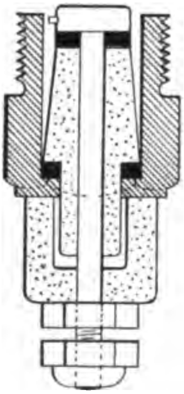


FIG. 213.

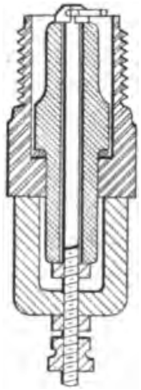


FIG. 214.

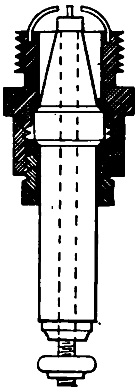


FIG. 215.

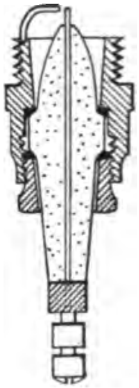


FIG. 216.

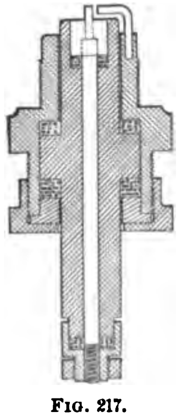


FIG. 217.

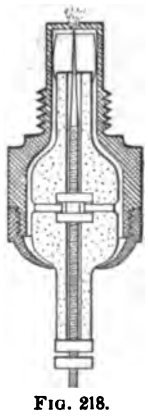


FIG. 218.

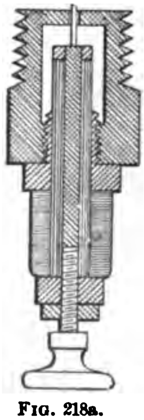


FIG. 218a.


FIG. 218b.

FIGS. 213-218.—Sections of Well-known Spark Plugs. The first six have porcelain insulation; the last two, mica.

substances that might be used, so as to destroy the insulation. In the second place, the constant splashing of the lubricating oil quickly befouls the plug, and the oil being burned and carbonized in the heat of combustion produces a deposit that allows the current to travel across the gap without sparking, thus destroying the efficiency of the plug until cleansed. Furthermore, if the insulating substance is cracked or soaked in oil, the short circuit occurs at some point short of the spark gap, involving that the plug must be replaced. Although, as already explained, the outside spark gap is highly efficient in overcoming very many spark plug troubles, it stands to reason that such as involve a breaking down of the insulation must be otherwise remedied.

FIG. 219.—Double Spark Plug used on the Cadillac Carriage. Unlike other plugs, the secondary circuit is carried by visible leads, and is not grounded at any point. Superior sparking qualities are claimed, and, as seems evident, fouling is a more remote danger.

Spark Plug Insulation.—The substances most often used in insulating spark plugs are porcelain and mica. The porcelain, as shown in the accompanying sectional views of typical plugs, is molded into the shape deemed most desirable by the designer and is pierced from end to end to admit the spindle of the positive electrode. Porcelain is well suited for the purpose of spark-plug insulation, since it possesses very high resistance both to heat and to the electric current. In fact, a high quality of porcelain should not break down with either the heat or the electrical tension encountered in gas engine operation. That porcelains are broken under such conditions is due to uneven heating of the insulating tube or to some unexpected violence. Its brittleness is nearly the worst objection to its use. Lower qualities of porcelain are, of course, much more easily broken, and thereby produce short-circuiting under ordinary conditions of temperature and electrical tension. Mica, a substance possessing an electrical resistance of 84,000,000,000,000 ohms per cubic centimeter is an ideal insulator, except for the fact that it frequently contains impurities that reduce its dielectric efficiency, and also because, owing to its laminated structure, oil and gas may be forced by the pressure of compression between the sheets composing the insulating sheath, thus, in time producing short-circuiting of the current. In order to obviate this trouble, one manufacturer, whose plug is shown among the sections, adopts the plan of tapering both the electrode spindle and the mica sheath around it, thus, as is claimed, producing a perfectly gas-tight joint, and, instead of allowing gas to be forced between the laminæ, providing for an increasing tightness of contact as the metal of the spindle expands with heat.

"Mica cores, built up of thin disks of sheet mica, even if carefully selected, are seldom free from iron, and the sheet mica cannot be so closely united as to entirely prevent a deposit of fine particles of carbon being pressed between the layers by the force of the explosions, thus rendering the insulation imperfect. This causes misfiring, and as the offending plug is to all appearances perfect, it often occasions the operator much annoyance.

"These remarks also apply to other substances, such as lava or artificial stone, which, being porous, are imperfect insulators."

Structural Points.—Practically all spark plugs of later patterns are made with an air-space at the end between one of the electrodes and the insulating core, in order to give opportunity for a "vortex" of air and gas to expel carbon deposits, as the charge is alternately compressed and expanded. Most mica-insulated plugs having the inner spindle sheathed with concentric coats of mica have also a cap at the end of the sheath to protect it and to ensure the attachment of the spindle. Many plugs using porcelain insulation have the porcelain in two or more parts, so as to avoid the troubles arising from uneven temperatures.

CHAPTER TWENTY-TWO.

THE DEVELOPMENT OF THE GASOLINE MOTOR BY GOTTLIEB DIAMLER AND HIS SUCCESSORS.

Daimler's Contributions to Explosive Motor Construction.—The use of explosive motors for propelling road vehicles was made possible by the inventions of Daimler, after whose designs practically all vehicle motors are constructed to the present day. The improvements introduced by him were principally those that made it possible to use a mineral spirit or liquid fuel, and the attainment of a higher speed than was possible with the older engines of the Otto type. With increased speed, a lighter weight and smaller proportions were made possible. The Otto engines in use until the date of his memorable inventions could attain only a very slow speed, both on account of the complicated and uncertain slide valve arrangements and also from the system of igniting the charge by the constantly burning gas jet and slide. Daimler struck at the root of the difficulties and constructed his earliest types of engine with the poppet valves, now in universal use, and with the familiar hot-tube ignition. This latter contrivance alone was largely instrumental in attaining the end of high speed, since, as already described, ignition is directly due to forcing of fuel mixture into the incandescent tube by the pressure of compression. This method of contact was, of course, impossible with the flame and slide ignition, as was also any very high degree of compression. Consequently, only the lowest speeds were attainable with the older Otto engines. Daimler, furthermore, constructed his cylinders with a stroke long in proportion to the total content, thus permitting such high compressions that the heat of the cylinder walls was sufficient to produce ignition of the charge, after the first few strokes ignited by the hot tube, or "priming-cap," as he called it.

Daimler Valve Governors.—The inlet valves of the early forms of Daimler engine were operated by atmospheric pressure acting against a vacuum created by the out-stroke of the piston, as in all gasoline cylinders of the present day. His exhaust valves were positively operated with the familiar cam-actuated push-rod, although the cam mechanism, instead of working on a secondary shaft, as at present, consisted of two eccentric grooves on the face of one of the inclosed fly-wheels, in which traveled a feather at the end of the valve rod.

By means of a switch operated by a simple governor, the feather running in the cam groove could be shunted from its regular course, so as to run in a nearly circular path, thus giving no motion to the exhaust valve, and keeping it closed. So soon, however, as the speed began to fall to the normal, the governor again shifted the switch, with the result of again resuming the operation of the valve, and exhausting the burned-out gases con-

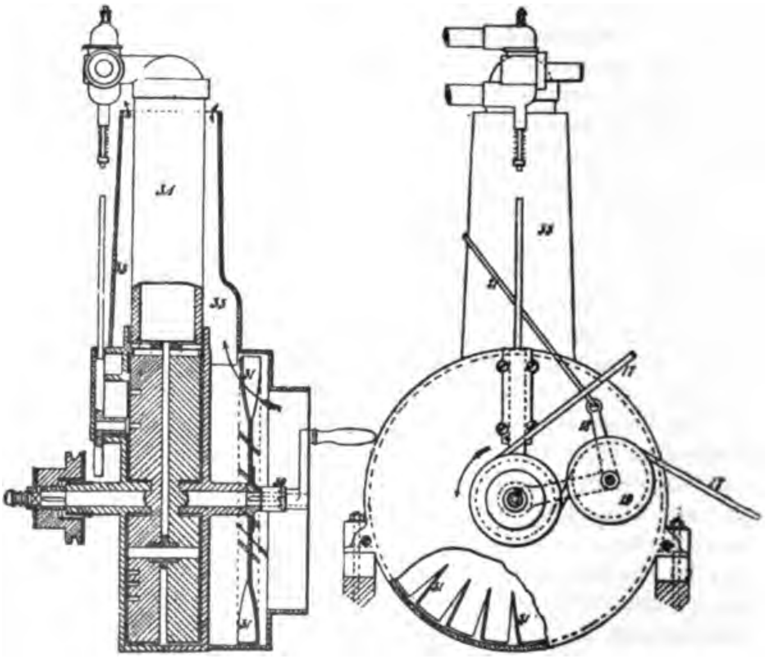


FIG. 220.—Diagram of the earliest Daimler Gasoline Motor; used on Daimler's first bicycle. The parts are indicated by numbers as follows: 17 is the driving belt passing around the pulley on the main shaft and tightened by jockey pulley, 19, and link, 21. 31 is a rotary fan, consisting of a number of radial fins as shown, which keeps a current of air passing through the air jacket, 33. 34 is the cylinder shown in part section.

tained within the cylinder. The shunting governor was speedily replaced by another form of valve-controlling device, in which a centrifugal ball governor on the main shaft was arranged to move a sliding sleeve outward and actuate an upright lever. The upper arm of this lever, moving inward toward the cylinder, deflected the push-rod working in the cam grooves, so as to make it miss the end of the valve rod, thus causing the valve to remain closed until the speed again falls to normal. A governing device of this description is shown in an accompanying figure.

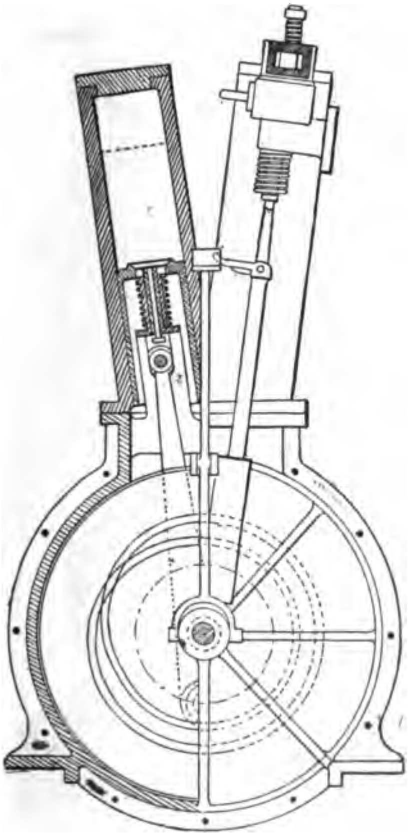


FIG. 221.—Part sectional view of the Daimler V-shaped Gasoline Engine, showing the air valve in the piston and eccentric cam grooves on the fly-wheel disc. The method of opening the exhaust valve is also indicated.

The Piston Air Valve of the Daimler Engine.—Another feature of the earlier Daimler engines was the supplementary air valve in the piston, the location and general construction of

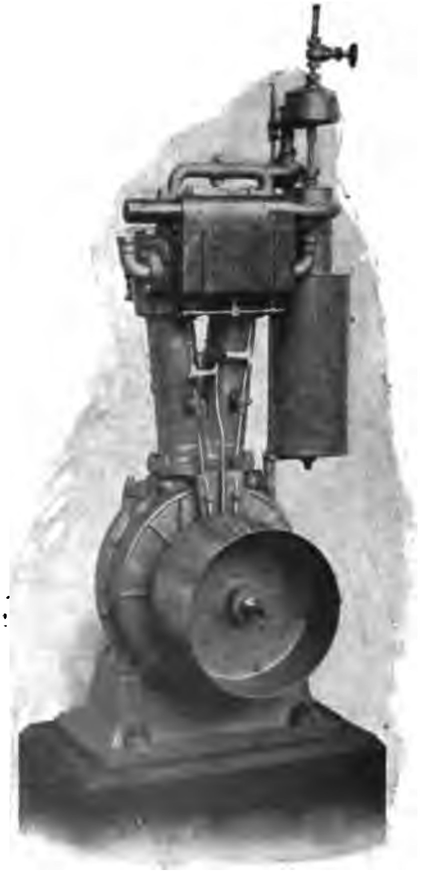


FIG. 222.—The Daimler V-shaped Gasoline Engine, with carburetter and parts attached. The object of constructing an engine with cylinders arranged as shown is to double the power capacity without correspondingly increasing the weight. This style of motor has been practically abandoned, and is no longer manufactured by the Daimler Companies.

which is shown in the half-sectional view of the V-shaped engine. The object was to compensate the imperfect operation of the surface curburetters used with these engines, and secure the injection of a sufficient additional quantity of air to secure the combustion of the charge. The operation of this valve involved that the crank chamber should serve as a reservoir for air admitted through a valve in its wall under suction of the piston during its in-stroke. On the out-stroke of the piston which draws in the fuel mixture through the inlet valves, the piston air valve is caused to open, by the superior pressure of the air in the crank chamber and in front of the piston. As shown in the half-sectional drawing of the V-shaped engine, the valve spring bears at one end against the inside end wall of the trunk piston and at the other against a shoulder sliding on the valve stem. On the out-stroke, accordingly, this shoulder comes into contact with the fork shown on an upward inside projection from the lower end of the cylinder, being forced upward and compressing the spring against the upper wall of the piston. The valve rod, being thus relieved from spring pressure, is free to rise in obedience to the superior pressure of the air within the crank case, which is forced in as the fuel charge enters from the opposite end. During the firing stroke the spring is similarly compressed, although, owing to the greater pressure of the expanding gases behind the piston, the valve is held in its seat. This piston valve was used on Daimler engines for only a few years, its function being afterward discharged much more satisfactorily by adjustable air inlet valves in connection with the carburetter.

The object sought in the V-shaped engine was to secure an upright construction, with the full effect of two cylinders operating on the same crank, thus saving both space and weight, in a manner impossible with opposed cylinders of long stroke.

Water Cooling and Ignition Devices.—In the early engines of the Daimler pattern the cylinder cooling was accomplished by means of a rotary fan worked on the crank shaft of the engine, and forcing the air through a form of jacket surrounding the entire upper portion of the cylinder. The floats of this fan are shown at the points marked 31 in an accompanying illustration, and the jacket at 33. By this device a constant current of cold air was forced against and around the cylinder. Of course, the later Daimler motors, designed for vehicle use, have the ordinary water-jacket cooling system, any form of air-cooling being evidently inadequate to the demands of even average traffic.

The hot-tube ignition is still used by the Daimler companies of Germany, England and America, as also by several of the French motor-carriage builders using the Daimler engines. This system is successful on account of the long stroke, characteristic of the Daimler cylinder, which gives a correspondingly high compression ratio, involving certain and efficient ignition of the charge at high speeds. However, certain European automobiles, such as the Mercedes-Daimler, have latterly been constructed with the primary circuit break-contact system, with current supplied by magneto-generators. Some of the later Panhards are equipped with the jump-spark ignition.

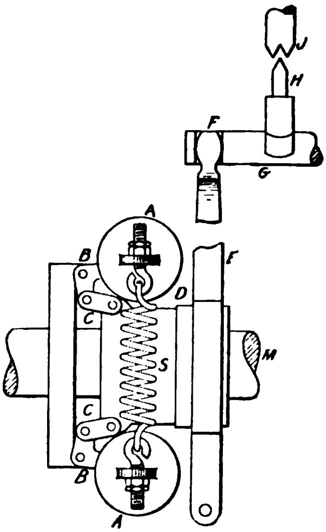


FIG. 223.—One type of Gas Engine Governor, which is an improved variation of the device used on the early Daimler motors. The parts are as follows: A and A, ball weights; B and B, bell cranks actuating the links, C and C, as the balls move outward resisting the tension of spring, S, and sliding sleeve, D, on the shaft, M. E is a lever arm attached to D, which moves the shaft, G, by contact at F, as shown, thus throwing the pick blade, H, out of contact with the end, J, of the exhaust valve rod.

Motors and Motor Design.—While an account of the motors used on gasoline automobiles must be historical, as well as descriptive, it would be frivolous to attempt describing all the typical forms that have been produced, or even to notice the greater proportion of those most conspicuous for success. Such a procedure would unnecessarily add to the size of this book, and at the same time thwart the end for which it is written—to give the reader a good idea of the constructive and operative principles involved.

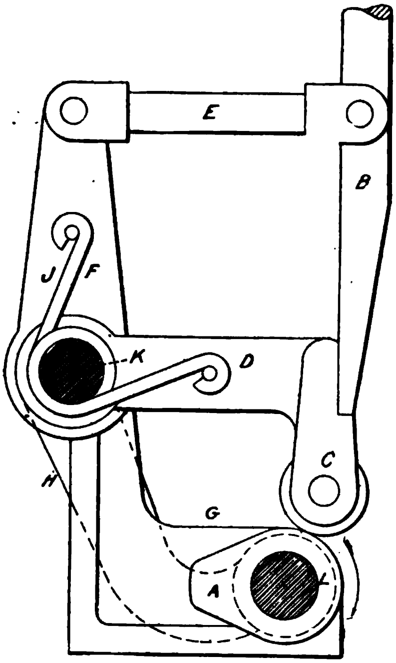


FIG. 224.—Governor Mechanism of the later Daimler Motors. As shown in this cut, the cam, A, bearing upon the roller, C, lifts the arm, D, pivoted at K, and held in position by a spring, J. By lifting arm, D, it also lifts pushrod, B, which opens the exhaust valve. When, however, the speed of the motor has increased beyond the predetermined limit a sleeve of varying diameter, sliding on the same shaft, L, to which the cam, A, is fixed, is moved so that the larger diameter is brought to bear against the downward extension, H, of the arm, F, thus causing F to incline on the pivot, K, toward the cylinder (at the right as in the cut), hence pushing rod, B, by link, E, out of range of arm, D, as it is moved upward by impulse from cam, A. In this case the exhaust valve is not opened and, the products of combustion being retained in the cylinder, there is no feeding of fresh fuel gas.

In general, all automobile motors correspond to one description of valve-operating and gearing. The principal points of variation touch such constructions as deal (1) with the special designs for increasing efficiency, and (2) for enabling more complete control, either automatic or manual. Under the first head may be included such elements of design as refer to the diameter of the cylinder bore and the length of the stroke, as compared to the horse-power rating, also to the speed at which the piston is designed to travel when the motor is yielding the highest output of power. The size, arrangement and position of the valves have also been modified by some designers, with a view to gaining various advantages, such as will be suggested later on. Several well-known engines depart from the generally-adopted plan in having the inlet valves positively operated, as are to exhaust valves; but this opens a question regarding which authorities are by no means agreed.

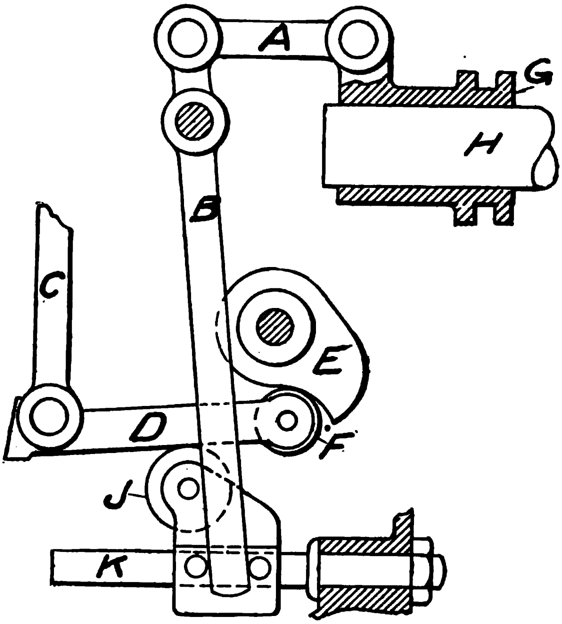


FIG. 225.—Mechanism of the Peugeot Variable Exhaust Valve Lift. A is a link attached to spool, J, sliding on the rotating shaft, H, as shaft G is slid backward or forward according to the impulses of the centrifugal governor. The link, A, actuates the lever, B, sliding the roller, J, on shaft, K. The roller, J, forming the fulcrum of lever, D, being thus slid backward or forward, varies the lift of valve rod, C, as actuated by the cam, E, bearing upon the roller, F.

In the matter of governing the motor several important considerations appear, and the designs still in use differ on the question whether regulations should consist in changing the fuel mixture, retarding the spark, or simply in interrupting the action of the exhaust valve. That any one of these methods may be effective seems to be acknowledged. Several motors are controlled by two such means. The question is largely one of economy of power and simplicity of construction.

Devices for Balancing Motor Operation.—Another problem of considerable importance in the design of a motor vehicle is how to secure a perfectly balanced operation of the motor. This is very essential, since not only will an unbalanced movement of the motor proceed a vibration that is at once annoying to the passengers and destructive to the framework of the carriage, but it also involves a very great loss of power. A single cylinder motor will necessarily cause considerable vibration when hung upon the light frame of the motor vehicle, which can take up and transmit the vibrations, due to compression in the cylinder, which offers a considerable resistance to the free rotation of the fly-wheel. The reason for this is obvious, for since in the ordinary four-cycle motor there is one power stroke in each two revolutions of the fly-wheel, there is necessarily considerable unevenness of motion. In the Daimler V-shaped engine the two pistons work upon one crank, the power stroke in one cylinder being contemporaneous with the suction stroke in the other, and the succeeding strokes of the cycles in both being in the same order. This arrangement secured a good balance from the reason that a power impulse occurred in every revolution of the fly-wheel. The V-shaped motor was used on all cars manufactured by the Daimler companies and by Panhard-Levassor and others go for the first few years of automobile history. This model was then abandoned for the parallel double cylinder motor, as it is known to-day. With the earliest double cylinder motors, however, the two cranks were set at 180 degrees, making the out-stroke in one cylinder simultaneous with the in-stroke in the other. This arrangement was adopted with the idea that balanced movement and neutralization of vibration should be thus best attained. However, in the later Panhard vehicles using double cylinder motors both piston rods work on a single crank pin, so that both pistons make in-strokes and out-strokes at the same time, as in the old V-shaped model. This is the plan now most usually adopted whenever only two cylinders are used. Four-cylinder motors are in this respect really double two-cylinder motors—two of the cylinders being always at out-stroke, and two at in-stroke.

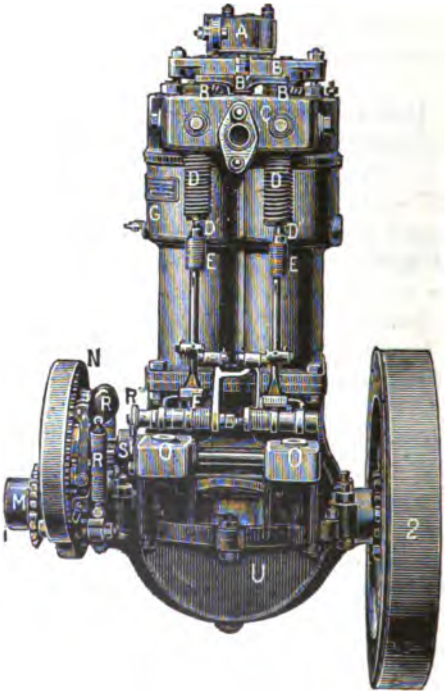


FIG. 226.—The Phenix-Daimler Double-vertical-cylinder Six-horse-power Motor, as used by Panhard-Levassor. A is the port for admitting fuel gas under piston suction; B, the inlet valve; B′, the exhaust valve; C, the ignition apparatus; D, spring on the exhaust valve; D′, exhaust valve rod; E, pushrod actuated by the cam; F, governor attachment; N, wheel on the cam shaft, carrying the governor; R, the centrifugal weights of the governor; R′, the governor springs; R″, sliding cam shaft; S, the cam actuating the exhaust valves; (2), the engine flywheel carrying the female cone of the main clutch.

Another type of motor very frequently employed where two cylinders are used is that known as the double opposed cylinder type such as is used on the Haynes-Apperson, the Stevens-Duryea, the Autocar and other American vehicles. In this type the two cylinders are set at opposite ends of the common crank chamber, the two piston rods working upon cranks set at 180 degrees. This, of course, involves that the cylinders are somewhat offset, so that lines drawn through the centres of each would be parallel instead of continuous. As may be readily understood, the effect of two oppositely-placed cylinders working upon cranks at 180°, is the same as that produced by two upright parallel cylinders working on the same crank. This is to say the two out-strokes and the two in-strokes are contemporaneous, the firing stroke in one cylinder taking place at the same time as the suction stroke in the other. Very few gasoline carriages use a three-cylinder motor, the most notable American example being Duryea carriage, which has three parallel cylinders working on cranks at 120 degrees. The manufacturers claim for this arrangement a higher degree of balance than is attainable with either two or four cylinders. Since only a part of a stroke in each cylinder is contemporaneous with another part of another stroke in each of the others, the vibration resulting from operation of the car is distributed throughout the cycles for the three cylinders, being thus completely neutralized. This result is explainea by the theory that in a multiple cylinder motor, with properly disposed cranks, the vibrations are properly decreased as the square of the number of the cylinders. This would give a three-cylinder

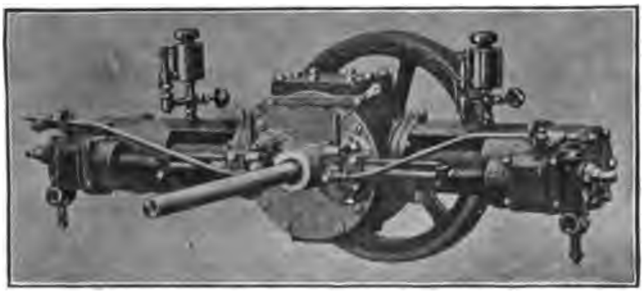


FIG. 227.—Double Opposed Horizontal Cylinder Motor of the Haynes-Apperson Carriages. The two cylinders of this motor are somewhat offset, as shown in the cut, the crank rods working on two cranks. The long crank shaft shown at the front of the engine is for carrying the change speed gear already described. The reciprocating parts are lubricated by adjustable oil feed cups shown at the top of each cylinder. Ignition is by break contact spark, the exhaust connections being on the same plan as those described for other motors. The inlet valves are operated by suction, and are at right angles to the positively operated exhausts.

motor nine times less vibration than would be possible with a single cylinder motor, and as between it and a two-cylinder motor the ratio would be as 9 is to 4. We may, therefore, understand that, since the vibration of a gasoline motor is to be attributed to the fact that the power rotating the fly-wheel acts but once in two revolutions a perfect neutralizing of vibration demands in a multiple-cylinder motor:

(1) That the flywheel should be as heavy as possible for the power rating of the engine, and of as large a diameter as is consistent with economy of space and power; so as to absorb as much of the vibration as possible, while maintaining good balance of movement.

(2) The cranks should be so set as to distribute the stages in the cycles of the several cylinders as much as possible so that the power impulses will be approximately continuous, as in a steam engine; the continual successions of power and no power being thus interrupted. By this means a greatly reduced strain is thrown upon the flywheel and the moving parts, with the result that the vibration and wear are equally reduced.

Data on Motor Balancing.—Until very recently the matter of motor vibration has been a serious consideration. Even with the greatest care in designing the trouble has not been overcome, and motors running free in some carriages have been observed to produce the most startling effects. On account of such results many designers, notably De Dion & Bouton of France, have long been known as advocates of the single cylinder, and have actually been very successful in producing motors in which vibration is minimized. This result has been achieved very largely by reducing the length of the stroke in proportion to the diameter of the piston—the most usual design being to make them equal—thus reducing the compression ratio, and by carefully regulating the weight of the flywheels. In short, the long stroke and high compression of the early Daimler motors have been found generally impracticable for vehicle work. With the De Dion carriages having the motor directly geared to the differential the compression of the motor may be used as a form of auxiliary brake, especially in coasting down hills, by simply interrupting the electrical ignition circuit and leaving the clutch connected—thus allowing cycular operations to be directly reversed, the road wheels driving the motor as an air-compressor. Under usual conditions this act would cause the motor to stop, but when going down hill, with the clutch in gear, the motion of the carriage will drive the motor, exactly reversing the usual order. The air, being constantly drawn into the cylinder space, is compressed on the in-stroke of the piston, thus furnishing sufficient resistance to materially decrease the speed of the carriage.

In connection with the relation of stroke length and neutralizing of vibration, the following data on prominent American gasoline automobile motors will be of interest:

NAME.	Number of Cylinders.	Bore in Inches.	Stroke in Inches.	D. H. P.	R. P. M.	RATIO.
Haynes-Apperson..	2	5	5	9	1,000	1—1
“ “	2	5¼	6½	...	1,200	21—26
Peerless	2	4½	5½	16	900	9—11
Packard	1	6	6½	12	850	12—13
“	4	3⅞	5⅛	20	750	31—41
Locomobile.......	2 & 4	4	5	9 & 16	900	4—5
Knox	1	5	8	8	900	5—8
“	2	5	7	16	....	5—7
St. Louis...... ...	1	5¼	6	7	500	7—8
Columbia.........	4	5	5	24	900	1—1
“	2	5	4½	14	....	10—9
Stevens-Duryea ...	2	4¾	4½	7	675	19—18
Cadillac..........	1	5	5	6½	800	1—1
Franklin	4	3¼	3¼	10	....	1—1
“	4	4	5	24	....	4—5
Autocar	2	4	4	11	900	1—1
Stearns...........	2	5¾	6¼	24	900	23—25
Duryea...........	3	4½	4½	10½	900	1—1
Apperson Bros....	2	5¾	6½	20	750	23—26
“ “	4	5	6	40	500	5—6
Pope-Toledo......	2 & 4	4¼	5¼	14 & 24	900	17—21
Oldsmobile.......	1	4½	6	4¾	600	3—4
Pope-Robinson....	4	4	6	....	750	2—3
Ford............	2	4	4	8	....	1—1
Winton...........	2	5¼	6	....	....	7—8

It will be seen that the majority of these engines have the piston diameter and stroke length very nearly equal, or the length of the stroke very little greater than the diameter. The Knox single-cylinder engine has the ratio 5 to 8, and the double-cylinder, 5 to 7, thus producing as claimed, the longest stroke carriage engine made in this country. The Knox engines are made, however, with a dome-shaped compression space, thus reducing the compression ratio below the figure that would otherwise seem to be involved. Only two, the Stevens-Duryea and the Columbia light car, have a piston diameter greater than the stroke length, but this innovation has proven advantageous in increasing power.

The Gobron-Brillie Motor.—While the familiar types of engine would seem to answer all requirements, when properly designed and constructed, several inventors, principally Frenchmen, have attempted to solve the vibration problem by extraordinary mechanical means. The most noted of these is the Gobron-Brillie double-cylinder engine, whose four pistons work upon a three-throw crankshaft. The cylinders are open at both ends, two oppositely moving pistons sliding in each, with the valves, ignition apparatus and compression space located midway in the length of the bore. As may be seen from the figures herewith given, the

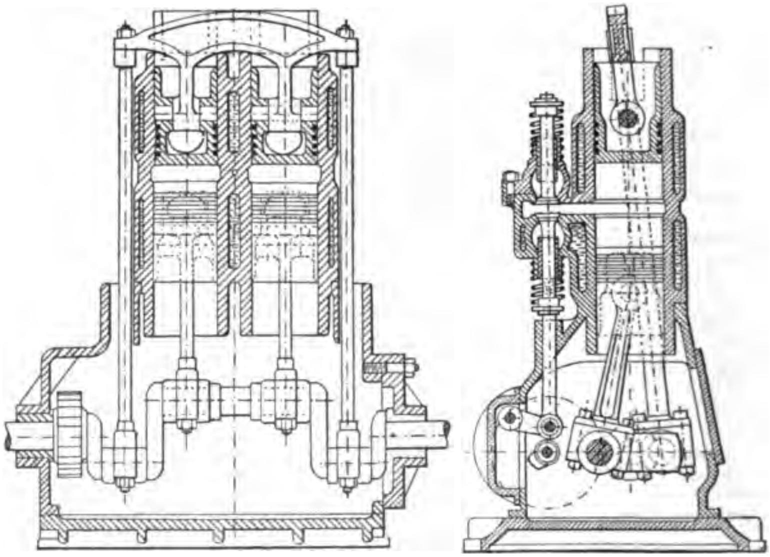
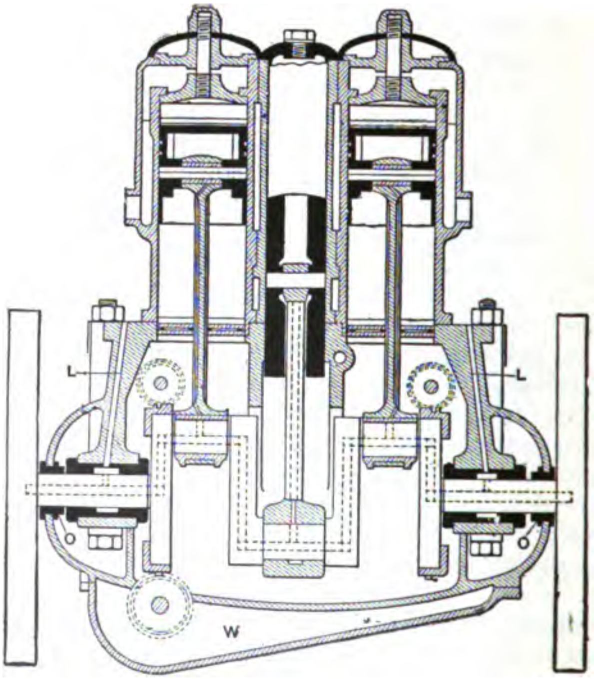


FIG. 228.—The Gobron-Brillie Two-cylinder, Four-piston Balanced Engine.

lower pistons work upon one crank, and the two upper pistons, through a crosshead bar at the top, upon two other cranks set at 180° from the first. The result is that both cylinders have the out-strokes and in-strokes of their pistons simultaneous—the power stroke in one cylinder taking place with the suction stroke in the other. According to the statements of experts, this arrangement is exceedingly efficient in overcoming motor vibrations, while the highest velocity of expansion is secured, the rate being nearly doubled, as compared with the ordinary type of motor. Of course, the connecting rods between the upper pistons and their cranks must be twice as heavy as those from the lower pistons to their common crank pin. Structually, the main advantage presented is that all joints are absent in the cylinders; hence no leakage is possible, as in some other motors.

The De Dion Two-Cylinder Motor.—De Dion & Bouton have attacked the vibrationless-cylinder problem very differently. They have constructed a double cylinder motor, the two pistons of which operate two cranks on the same line—virtually working one crank, like other double cylinder-motors. Between the two power cylinders, however, is a third, in which slides a piston geared to a crank at 180° from the other two. This third piston is used solely for balancing, having no function either in transmitting power impulses or in compressing gas. In order to obtain perfect results, the balancing piston and its connecting rod must be of exactly the same weight as the two power pistons with their connecting rods, and since it always moves in the opposite direction from them, it is extremely efficient in equalizing the stresses of motor operation. The end of perfect balance is further advanced by the use of two flywheels, one at either end of the motor shaft. The valves are operated by worm gears on drums at either end within the crank case. A third worm gear rotates a pinion governing the oil circulation in a manner both interesting and effective. As shown by the dotted lines in the drawing, oil ducts are drilled throughout the crank, shaft, piston rods and wrist pins, being forced by the pump through all these ducts to the several bearings and to the cylinder walls, from the leads *LL*, opening at the top of the crank case. Leakage of oil is prevented by special guard bearings at *OO*, the surplus of oil being caught in the wall, *W*.

Automatic Governing Devices.—Next in importance to securing perfect balance, when the motor is running evenly, is the question of regulating the speed, so as to prevent racing of the motor and loss of proper control. For this reason most gasoline vehicle engines, from the days of Daimler's first carriages, have been fitted with some sort of automatic governing device. As already stated, such devices have operated either to prevent the opening of the exhaust valve, to retard the spark, or to modify the fuel mixture. In accompanying diagrams are shown various types of device for governing gasoline engines. The first represents the general type used with Daimler's early engines. Here a centrifugal ball governor acts to shift the sliding sleeve on the governing shaft, and to draw away the pick blade used to push



AUTOMOBILE.

FIG. 229.—The De Dion & Bouton Two-cylinder, Three-piston Balanced Engine.

up the end of the exhaust valve rod, from the path of the actuating cam. This type of governing is more frequently used on stationary gas engines, and is very effective; reducing excessively high speed by simply preventing the burned gases from escaping from the cylinder. In this act it also interrupts further supply of fuel, thus interfering with the operation of the engine until the speed is reduced again to the proper point. In later Daimler engines the sliding sleeve operated to shift the position of a lever connected through a link with the end of the valve rod, the end of the valve rod being pushed away from its normal support, and out of the path of the actuating cam, as is shown in the accompanying illustration. A much more practical device is the Peugeot variable exhaust valve lift, in which the end of the exhaust valve rod is attached to a lever, whose fulcrum is shifted by the action of the governor from a point at which the movement of the cám produces the greatest lift of the valve, to a point at which the valve

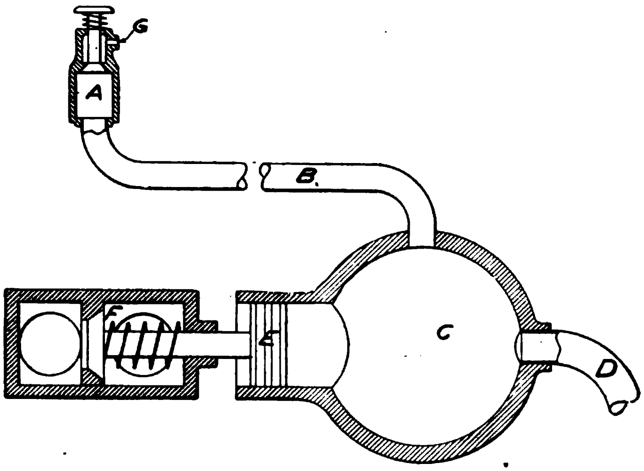


FIG. 230.—Diagram of the Winton Pneumatic Speed Control System. A is the valve chamber from which the air is exhausted through the vent, G, by pressure on the foot button at the top of the valve rod; B, a tube connecting chamber, A, with air reservoir, C; D, tube leading from the air pump operated from the main shaft of the engine, and feeding compressed air into the reservoir, C; E, the piston attached to the spindle of the inlet valve, F, and controlling the opening of F, according to the degree of compression maintained within reservoir, C. By this mechanism the opening of the inlet valve, and consequently the fuel supply, is regulated within definite limits, and the speed varied as desired.

is left completely stationary. The operation may be understood by the illustration.

Winton's Pneumatic Control.—Very many gasoline carriages of American build have no automatic regulation of the engine, depending for speed and power control solely upon the act of the chauffeur. Of this kind is the Winton pneumatic regulator for controlling the inlet valve, as shown in an accompanying figure. The details are as follows: A small air pump, driven by a connecting rod from an eccentric on the main shaft, which is fixed at 180° from the crank, constantly supplies air to a special reservoir where it bears upon a piston fixed at the end of the rod of the cylinder inlet valve, so that, according to its pressure, it can control the amount of fuel admitted to the combustion space. The operation is very simple and reliable, since the air behind the piston just mentioned can escape only when the push button, coming through the floor to the driver's foot, is depressed. It consequently follows that when the speed of the engine has ex-

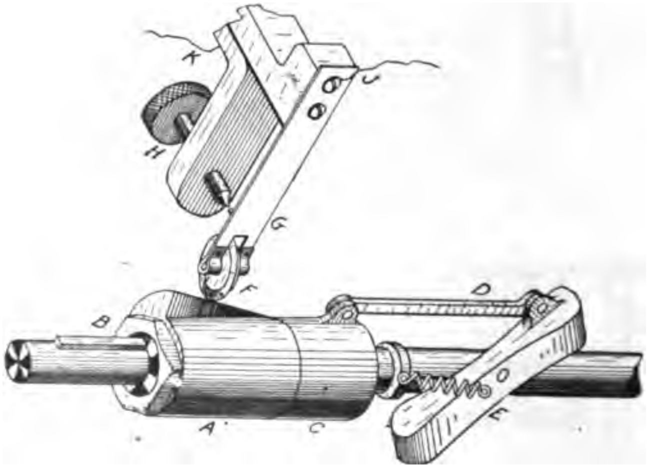
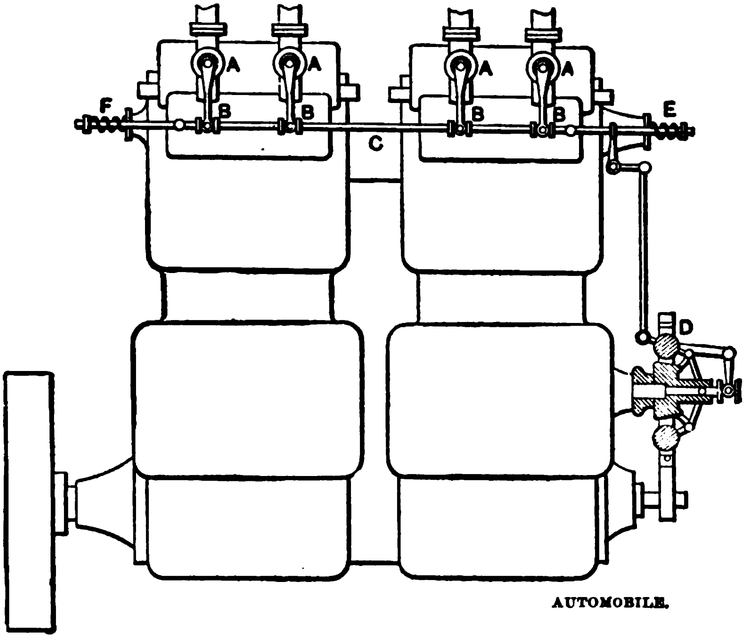


Fig. 231.—The Sliding Cam Ignition Governor of the "Packard" Carriages. A is a sleeve sliding on a feather, B, on the rotating shaft, being connected by link, D, to the governor weight, E, so that the throw of the cam, F, may be varied from maximum to zero, as the speed of the motor increases. Cam, F, bears upon the roller carried on the end of the vibrating leaf spring, G, modifying the electrical contact between the terminals, J and K, according to the throw of the cam and the adjustment of the screw, H.

ceeded a certain predetermined limit the air exhaust cannot take place with sufficient rapidity to enable the usual operation of the feed valve to continue; hence it acts as a cushion or spring, resisting the opening of the feed valve until the speed has again sunk to the desired point. By pressing on this button the speed of the engine may be varied through a range between 100 and 800 revolutions per minute.



AUTOMOBILE.

Fig. 232.—Diagram of Volume Throttling Device on the Mors Engine. A and A are throttle valves on the inlet pipes; B and B, valve levers; C, valve shaft, under control of the governor, D; E and F, springs, used either singly or together, according to control, so as to vary the opening of the inlet. System like the Duryea.

The Packard Ignition Governor.—Another American carriage, the Packard, is equipped with a foot-operated inlet-valve controller, by which the speed of the motor may be regulated up to 850 revolutions per minute. In addition to this, there is a very ingenious governing device operating from the camshaft to the motor, which at high speed modifies the spark to any required point, or prevents it altogether. This result is accomplished by a sliding sleeve, actuated by the centrifugal governor, which moves a variable cam across the periphery of a roller attached to a contact spring used to make the ignition circuit. When the speed of the motor exceeds a predetermined limit, the cam overruns the roller and ignition is prevented. The variable cam also has a toe lying screwwise around the sleeve, so that it actuates the roller sooner at high speed than low speed, thus automatically timing the ignition as nearly as possible to the proper moment for maximum efficiency.

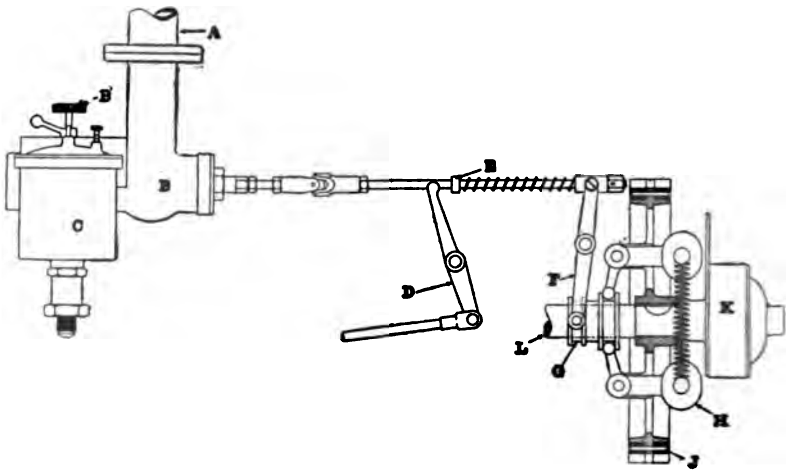
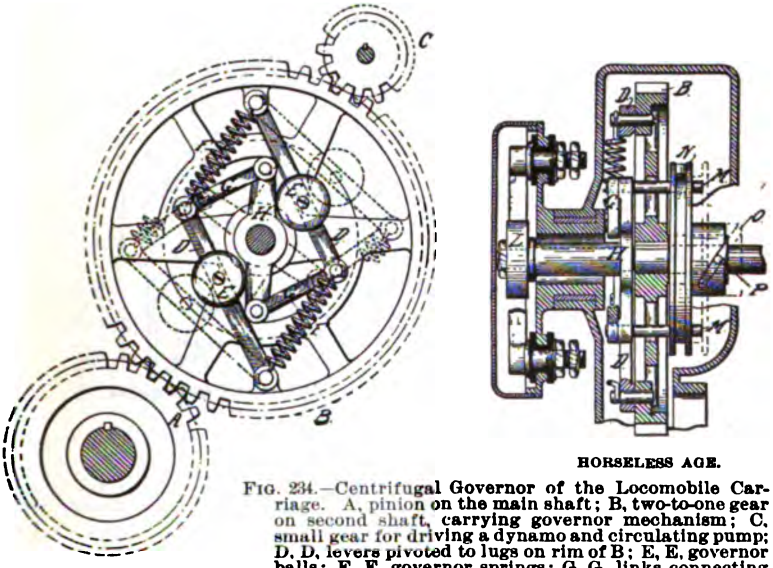


FIG. 233.—Automatic Governor and Hand Throttling Connections of the Toledo Motor. The parts are: A, the suction pipe of the carburetter; B, the carburetter; B′, the needle valve on the float chamber; C, the float chamber; D, throttle controller on rod, E; F, the governor lever; G, the sliding governor sleeve; H, governor weight; J, fibre gear on cam shaft; K, sparking commutator; L, cam shaft.

Throttling Governors.—The majority of modern motors have apparatus by which the time of the spark may be regulated by the driver, and with very many of them the same result is achieved by automatic governing. In many senses, however, throttling seems to be the most approved method of governing. With the Centaure motor of Panhard-Levassor the centrifugal governor acts to move a sleeve along its shaft, and thus, at high speeds, to reduce the quantity of gas mixture coming from the carburetter, through a piston rod, link and lever, as shown in an accompanying diagram. The same result may be achieved at the will of the driver by means of a foot pedal or hand lever—often both are provided—independent of the mechanical conditions in which the governor operates. A very similar arrangement is used on the Pope-Toledo; the hand-throttling gear operating on the same link as the automatic centrifugal governor. The arrangement of the throttling and spark-control handles is shown in a previous diagram of the steering wheel of this carriage.



HORSELESS AGE.

FIG. 234.—Centrifugal Governor of the Locomobile Carriage. A, pinion on the main shaft; B, two-to-one gear on second shaft, carrying governor mechanism; C, small gear for driving a dynamo and circulating pump; D, D, levers pivoted to lugs on rim of B; E, E, governor balls; F, F, governor springs; G, G, links connecting lever arms to double armed bracket, H, turning it when the balls fly out to positions shown by dotted lines; L, commutator wheel of ignition circuit-maker; M, M, lateral studs on bracket, H; N, grooved collar rotated by studs; O, sleeve on N, having a spiral slot which works on pin, P.

The Riker Governor.—The governor used on the Locomobile gasoline carriage, for automatically effecting the throttling of the carburetter and the retarding of the spark, is a good example of the designer's skill. As shown in the accompanying diagrams, the arms carrying the governor weights actuate links at right angles to their normal position, and cause a sleeve on the governor shaft to turn on the shaft through part of a revolution, according to the speed of the motor. The part rotation of this sleeve serves to retard the spark by shifting the contact of the sparking commutator. At the same time, two pins, attached to the sleeve arms and projecting through the gear into the opposite direction, give a similar turn to the governor shipper loosely let on to the governor shaft. This shipper has a hub with a spiral groove, through which projects a pin fixed into the shaft, as shown. By the part revolution given the shipper by the pins the hub moves backward along the shaft as far as the pin in the groove will allow it, thus actuating a link for throttling the carburetter. As the engine slows down, the sleeve holding the commutator cam returns to its position, and the pins acting on the shipper move the slotted hub into normal position, restoring the full feed of fuel mixture. In starting the motor, the driver reverses the lead, retarding the spark until the full speed is attained, then leaving control to the governor.

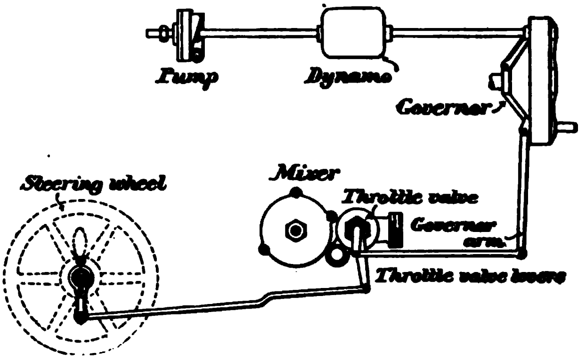


FIG. 235.—Diagram of the Governor and Control Connections of the Locomobile Carriage, showing manner of automatically and manually throttling the carburetter.

Gasoline Motor Construction.—In the construction of gasoline engine cylinders experience has pretty clearly established one point—that the cylinder, with explosion and valve chambers, should be cast in one piece, and that no joints to be closed by bolts and gaskets should exist above or behind the power face of the piston. While all manufacturers do not adhere strictly to this rule, it nevertheless remains true that many difficulties have been experienced with leaking joints, and that the plan of avoiding them altogether is followed by some of the best authorities in the automobile world.

Exhaust Valves.—In regard to the operation of the exhaust valves, the standard practice is to open with a pushrod operated by a rotating cam, rather than by the use of eccentrics and straps or by grooved discs of the Daimler type. Regarding eccentrics it may be stated that they are used on a few motors that have the inlet valves positively geared, but are not popular for ordinary purposes. The Daimler grooved disc arrangement was revived some years since in a bicycle motor, as shown in a Fig. 140, but are practically abandoned on carriage motors, in favor of the more reliable shaft cam.

Positively Operated Inlets.—Several recent motors have the inlet valves positively operated either by shaft cams or eccentrics. The object sought is to render the operation of the valve perfectly regular, preventing breakage from rapid movements; also to allow of a higher initial pressure, since none of the force of suction is expended in maintaining the compression of the valve spring, and a greater quantity of fuel mixture can enter the cylinder. Other authorities object to this arrangement on the grounds of economy and efficiency. Thus one prominent manufacturer says:

"Experience has taught that the positive cam-actuating inlet valve is not nearly as efficient as the older forms. We are able to state this positively, having been pioneers of positive action construction, which has been discarded by us for the past two seasons. The reason for this change is not hard to seek, as in the positive valve type it is necessary, unless the walking-beam system is resorted to, to allow a large compression space in the head, which absolutely reduces compression in itself and causes a loss of power. The walking-beam system causes complication and trappiness. The automatic system is free of this objection, and with the advent of nickel-steel in valve construction, the question of breakage of these rapidly moving parts has been satisfactorily solved."

The facts remain, however, that several manufacturers, claiming as high a speed capacity as between 800 and 900 revolutions per minute, which is the average for the engine mentioned in the above quotation, still use positively-operated inlet valves, and claim good results. Several of the best makes of French carriage motor now have the positively-operated inlet valves, notable among these being the Mors, Darracq and Decauville.

Gasoline Motor Development.—While the earliest carriages built on the Daimler models used motors that embodied the original theories of the inventor—high piston speeds and a stroke sweep long in proportion to the diameter of the piston—designs were gradually modified so as to approximate models accepted at the present day. In the V-shaped engines used on the earliest Daimler carriages the ratio between piston diameter and stroke length was as 3 is to 5. For the purpose of obtaining superior balance and better efficiency, this was gradually reduced, until in the Phenix-Daimler, double-cylinder, 6 horse-power motor of 1899, the figures were 3 and 4—the piston diameter being 90 mm.

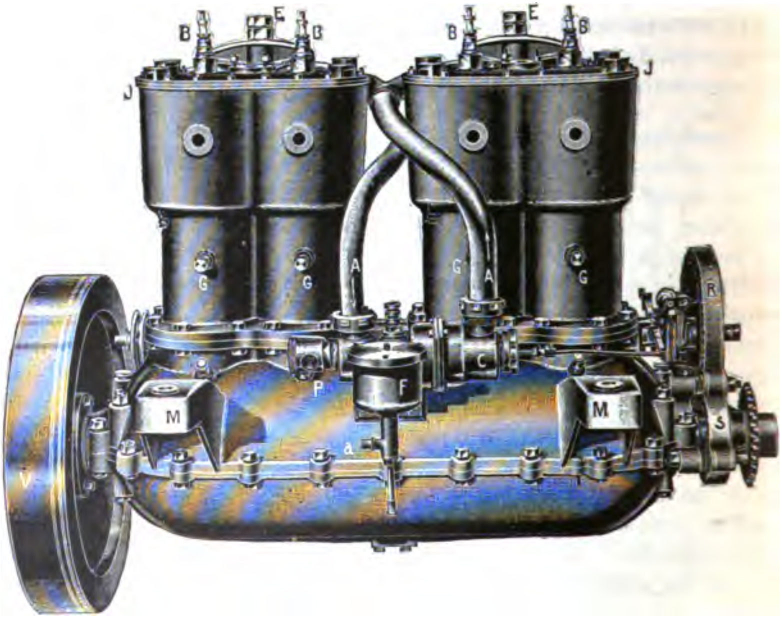
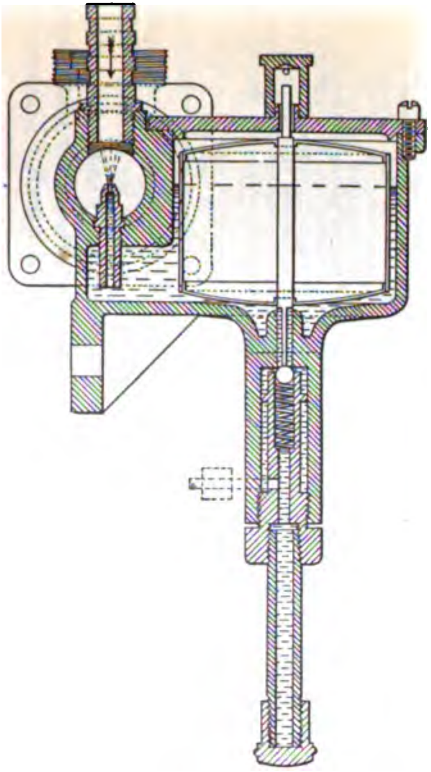
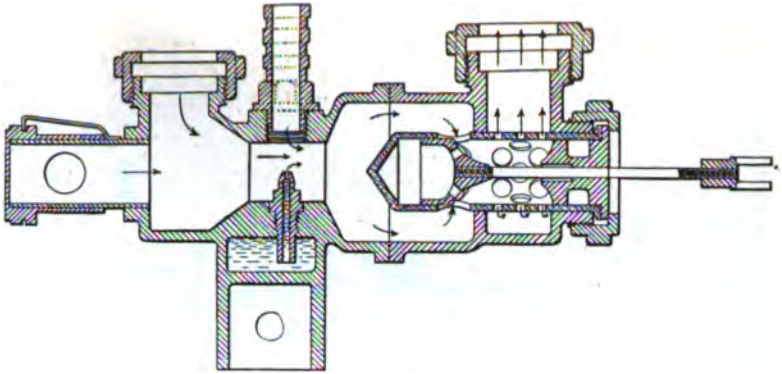


Fig. 236.—The Panhard-Levassor, 40 Horse-power "Centaure" Motor. A and A, tubes leading to and from the carburetter, the one on the left for conveying hot air from near the combustion space, that on the right for feeding the mixture into the cylinders; B, B, B, B, sparking plugs; C, mixing chamber of the carburetter; E, E, nuts securing yokes for holding inlet valve chambers in place; F, float chamber of carburetter; G, G, G, G, ports for attaching lubricating tubes; J, J, cylinder head plates; M, M, hangers for attaching motor to carriage frame; R, gear on two-to-one shaft carrying governor mechanism; S, gear on main shaft; V, flywheel; *a*, port for admitting gasoline to the carburetter.





FIGS. 237 and 237a.—Sectional Diagrams of the Centaure Carburetter of Panhard-Levassor. This is the earliest successful governor-controlled carburetting and mixing apparatus. As may be seen, it consists of the usual float chamber and vaporizing nozzle. The float, however, instead of controlling a needle valve, carries a ball on the end of its spindle, which is held close against the inlet port by a tension spring. The liquid spirit is admitted to the supply tube beneath the float chamber, where the short pipe and union nut are shown. The mixing chamber has a port to the left of the spraying nozzle, through which hot air is admitted from the head of the cylinder, as shown in the previous figure of the engine. A constant air supply enters at the port immediately above the nozzle. A variable spring-controlled air inlet is shown at the left. The mixture on its way to the cylinder passes through a perforated cylinder, within which slides a piston, as shown. This piston, slid to the right, closes the inlet admitting a smaller fuel supply. Its rod is attached to the governor slide, and the fuel inlet is thus controlled.

(3.54 inch) and the stroke length 120 mm. (4.72 inch). This motor developed 6 horse-power at 700 revolutions. The clearance space was concaved, and the compression pressure was 60 pounds. As shown in the accompanying illustration, the Daimler shaft-cam governor was used for automatic regulation of speed. The two cranks were set at 180°. The castings were in four parts; the cylinder heads and valve chambers being separable from the cylinders, and the crank chamber, consisting of an upper and a lower member, bolted together on flanges, as shown. The Phenix, or modified Maybach, carburetter, already described, was used with this engine, and the Panhard-Levassor clutch and speed gear transmitted its power to the road wheels.

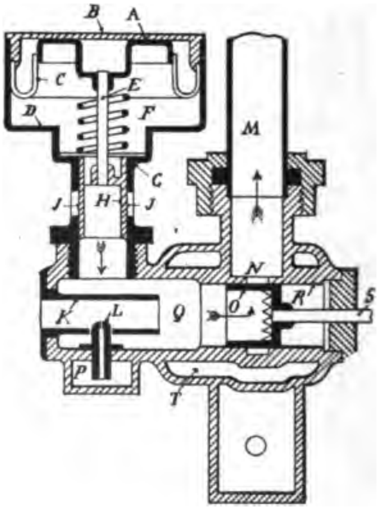


Fig. 238.—Section of the Krebs Mixer used with the later Panhard-Levassor Engines. The float chamber and other parts are identical with the Centaure carburetter. Gasoline comes from the float chamber through channel, P, and spraying nozzle, L, air being admitted at K. Q is the mixing chamber from which the air and gasoline gas passes into the feed tube, M, through the port, H, whose opening is controlled by the position of the serrated perforations in piston, O, moving through bore, R, as controlled by the governor through piston rod, S. When more air than the fixed quantity admitted at K is required by the conditions of motor operation, the suction of the motor piston depresses the small piston, A, held in cylinder, F, by the spring, E, and sliding in the elastic diaphragm, C. Air is admitted above it through a small port at B. The depression of piston, A, and causes the slide, H, to move downward in tube, G, thus opening to a greater or less degree the ports, J and J, admitting the required amount of air for any given condition.

Multiple Cylinders: The Panhard.—The demand for high-speed high-powered cars led very soon to the production of four-cylinder motors, of which the Panhard-Levassor Centaure is the type. The 40-horse-power motor is shown in an accompanying illustration. Here, as may be seen, the four cylinders are cast

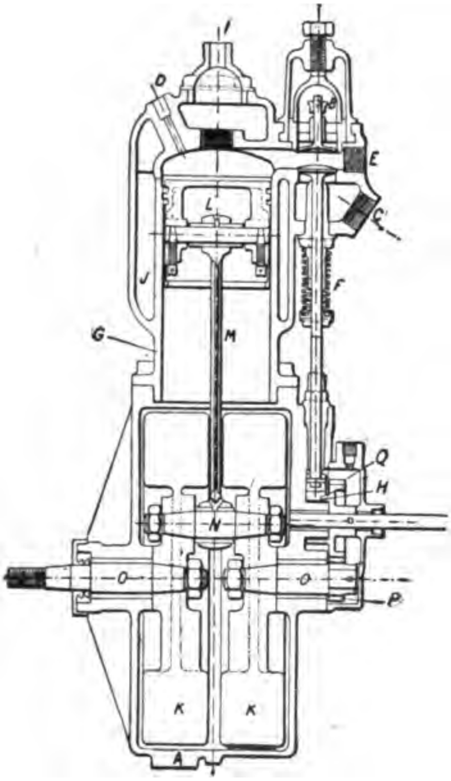


FIG. 239.—Section of the De Dion & Bouton Water-jacketed Carriage Motor. Parts are as follows: A, crank case formed by two cylindrical pieces bolted together; B, the inlet valve for the fuel mixture from the carburetter; C, the exhaust valve, held closed by a helical spring, F, and opened by the cam, H; D, the opening for the compression tap; E, the threaded hole for the sparking plug; F, the spring on the exhaust valve rod; G, the cylinder; I the port of exit for the jacket water from jacket, J, the inlet being at a point near the base of the jacket; K and K are the flywheels, or crank discs, which are joined together as shown, by the crank pin, N; M is the connecting rod; N is the crank pin; O and O are the crank shafts, that on the right carrying the pinion, P, that on the left being threaded for connection to the driving gear; P is a pinion on the crank shaft meshing with gear, Q.

in two separate pairs integral with their valve chambers; each pair being capped by head plates bolted to the casting. The automatic carburetter control and manual throttling connections are plainly shown, also the common fuel feed and hot air tubes *AA*. This is essentially the model of motor still used on heavy Panhard carriages; its simplicity and high efficiency having contributed to its well-earned popularity. As may be seen from the cut, the ratio of diameter and stroke length is about the same as that of the Phenix. Attachment to the carriage frame is by the hangers, *MM*.

The De Dion One Cylinder Motor.—The De Dion motors were among the earliest improvements on the original Daimler models. The aim sought in their design was to attain complete balance of motion with a single cylinder and this was accomplished, as already suggested, by the use of carefully-calculated heavy flywheels and equalization of the stroke length and cylinder diameter. In the single-cylinder light carriage motor, a diameter and stroke of 80 millimeters (3.15 inches) enables the development of between 5 and 6 horse-power at 1,800 revolutions. As shown in the section, the cylinder, head, water jacket and valve chambers are cast integral; no joint existing above the power face of the piston, save the opening for the compression tap at *D*. This type of motor, long noted for high efficiency, is intended to be direct-connected through the speed gear with the rear axle, as suggested in other places. It is peculiar among carriage motors in having the two flywheel discs—a further contribution to balancing movement—enclosed in the crank case, with the crank pin inserted upon a radius of both. Double cylinder De Dion motors, both with and without the balancing piston, are now made for heavy carriage and wagon use; the former type being the favorite for heavy trucks.

The Packard Engine.—The Packard four-cylinder engine is typical of the class having positively-operated inlet valves. Unlike the majority of such engines, however, both inlets and exhausts are operated from one cam shaft on the same side of the cylinders. With most typical engines of this class two camshafts, each operated by two-to-one gearing from the main shaft, are set on opposite sides of the engine, so that the inlet valve chambers are opposite to the outlets. Such an arrangement is shown in the plan view of the Decauville carriage. The object of this latter arrangement, which is reproduced by the American Peerless engine, and others, is, of course, to allow sufficient room for the supply and exhaust pipes to the cylinders. With the Packard engine the supply pipe is carried from the carburetter, set on the right side of the engine, over the top between the two middle cylinders, as shown in the sectional elevation and plan views of the carriage. In the section of the engine the inlet valve chambers are seen at the outside ends of each pair of cylinders, the exhausts being placed between them. As shown in the elevation of the carriage, the exhaust is carried off at the left side to the muffler. On the right side is also the entrance for the jacket water, which is let off at the top between the cylinders of each pair. The jackets completely cover the long sweep of the pistons. The oil duct to the crank case carries oil down between the pairs of cylinders. The commutator is operated by bevel gearing from

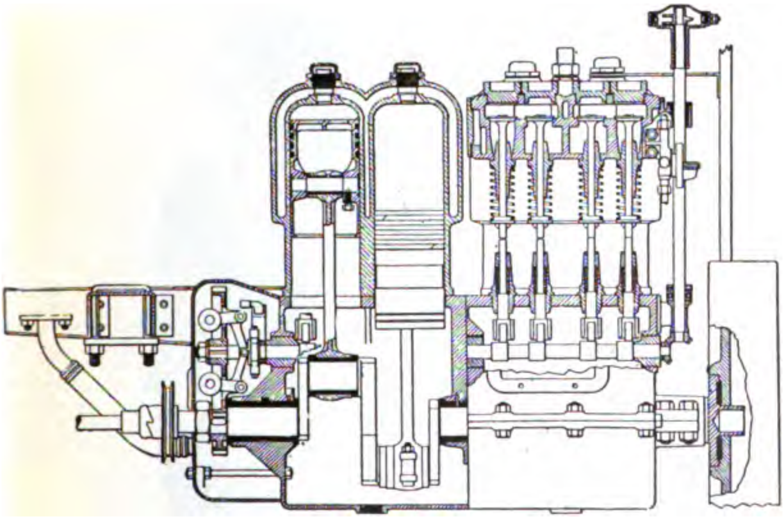


Fig. 240.—Part Sectional Elevation of the Packard Four-cylinder Motor, showing method of driving the inlet and exhaust valves from a single cam shaft.

the cam shaft, being shown at the top of the vertical spindle to the right of the diagram.

The oil is distributed by a force pump operated by an 80 to 1 reduction. It has four ball valves controlled by tension springs, to balance the siphoning of the oil column.

American Motor Development.—Motor development in America may be said to have been almost independent of things done abroad. As in every other mechanical branch, designers and inventors sought from the first to produce something distinctive, and were inclined to reject the achievements of French engineers, whose products often seem needlessly complicated to the American mind. Thus it was that the standard motor models of Daimler and Panhard-Levassor were rejected in favor of some-

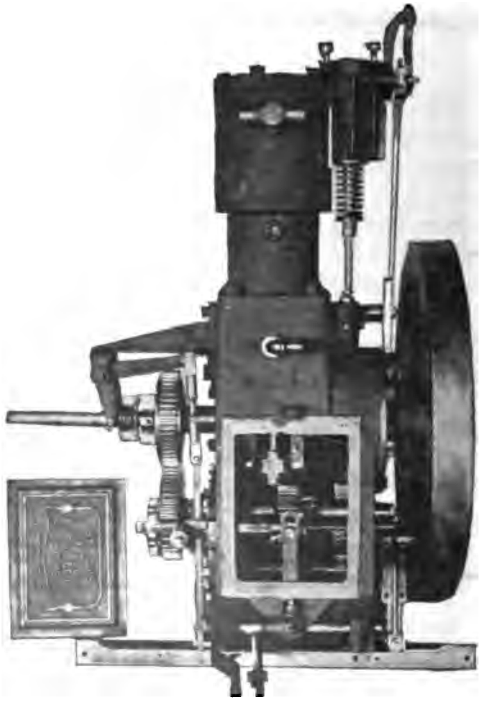


FIG. 241.—Single Cylinder Motor of the St. Louis Gasoline Motor Carriage, showing control levers and the variable speed gear contained within the case below the crank.

thing yet to come that should be thoroughly original. The typical European shift-gear transmissions were also rejected for the planetary and constantly meshed types, which may be said to be America's real contributions to automobile development.

It may not be too much to say that all distinctly American motor carriages have begun their history with the single-cylinder motor. This was the case with the Duryeas, Winton and several other pioneers. To-day we have the three-cylinder Duryea carriages and the double-opposed cylinder, Stevens-Duryea. Winton has followed the general development and is now building a double-cylinder motor with several original features. Other popular carriages, such as the Packard, the St. Louis, the Knox, all staunch advocates of the single cylinder, have latterly adopted double cylinders. Only the light Oldsmobile, the Cadillac and the

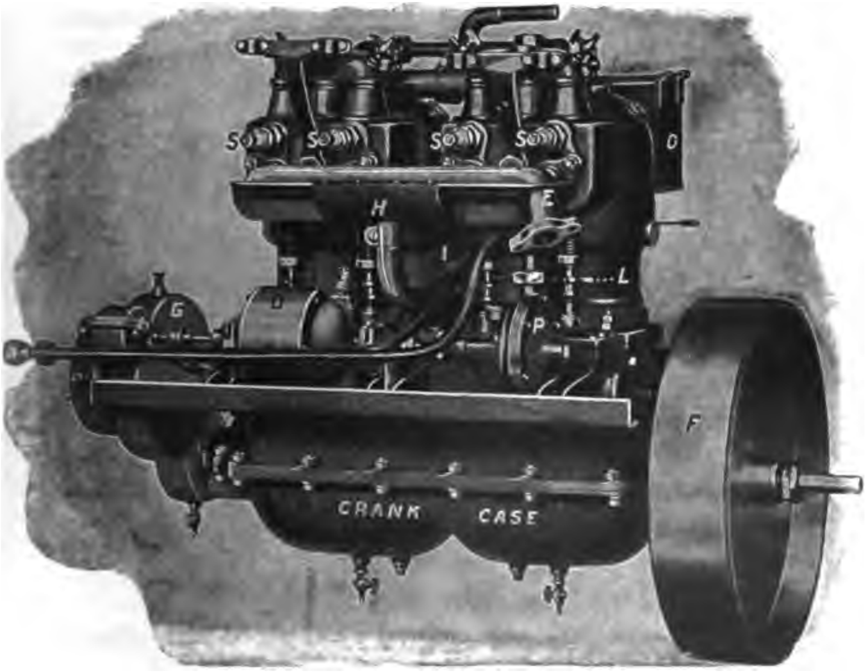


FIG. 242.—Four-cylinder Motor of the Locomobile Carriage. D, dynamo; E, exhaust pipe; F, flywheel; G, governor; H, air heater for carburetter; L, lug on cylinder wall, as fulcrum for tool in removing exhaust valves; P, centrifugal pump; O, oil tank; S, S, S, S, spark plugs.

Crest among light carriages adhere strictly to the original plan. However, most of the cars of recent origin are driven by 2 or 4-cylinder motors, and, as we shall presently learn, the general tendency among such is toward following the designs set down by French prototypes.

The Riker Motor.—Among the most interesting of recent American carriage motors is that used on the Riker-Locomobile carriages. There are two models; the 2-cylinder, 9 horse-power and the 4-cylinder, 16 horse-power, both capable of a 25% output above rating at increased speed. Both have a piston diameter of 4 inches and a stroke of 5 inches, developing their rated power at 900 revolutions. Each pair of cylinders is cast in one piece with the heads, water jackets and valve chambers, according to the design most widely approved by American engineers. A particularly interesting structural feature is found in the intake valve chambers, which are closed, so as to be readily accessible by cone-shaped bonnets held in place by yoke covers, readily detachable by means of a single clamping bolt, as shown in accompanying figures.

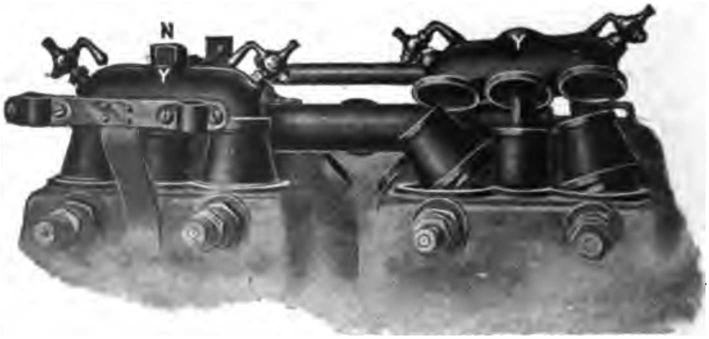


FIG. 243.—View of Locomobile Motor Inlet Valves, showing ease with which they may be removed.

Each 2-cylinder casting is bolted to the upper member of the crank case, which is of bronze, the lower member being of aluminum. The former carries arms for attaching the motor to the frame of the wagon. The main shaft of the four-cylinder engine is in one piece, consisting virtually of two double-throw parts, the cranks in each being set at 180°. The inlet valves are operated by suction, and the exhaust from cams rotated by a two-to-one reduction from the main shaft. A third parallel shaft, carrying the sparking dynamo and circulating pump, is rotated through a large gear on the cam shaft. In case of accident to the pump the circulation system is so arranged that the deficiency

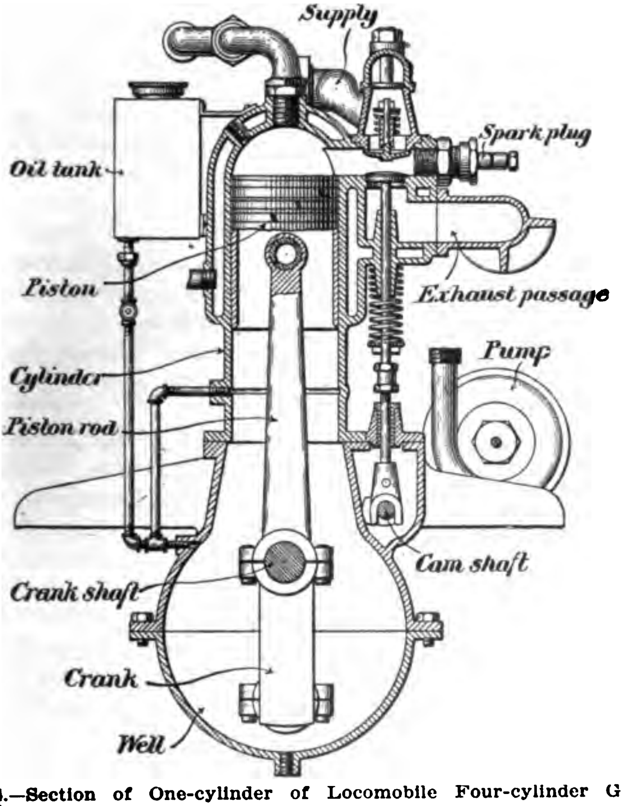


FIG. 244.—Section of One-cylinder of Locomobile Four-cylinder Gasoline Engine.

may be supplied by gravity at any time. The ignition circuit is supplied at starting by a battery of two 40-ampere-hour storage cells, which are automatically cut out when the dynamo has taken up speed. A separate coil for each cylinder, makes the connection of every plug separate. In the special non-sooting plug designed for this motor, an annular space between the porcelain core and metal housing, provides a vortex with each alternate compression and expansion, carrying off any carbon deposits resulting from the ignition of the charge. The outside spark-gap in the form of a chain connection between cable terminal and plug ensures sparking, even when deposits have collected. This is a feature now popular in a large variety of forms, of which Mr. Riker claims to have been the first discoverer in this country.

The lubricating system is of interest, as securing an even flow of oil and preventing excess. The supply tank is set at the head of the stand pipe beside the cylinder head, the viscosity of the oil being maintained by the heat of the wall. The standpipe leads oil to the crank case, and the interior of the cylinder is evenly lubricated by splashing. Excess is prevented by a groove on the inner circumference near the lower end of the piston sweep, where the overflow may be collected into a vertical return pipe parallel with the main feeder, as shown. Overflow pipes, extending into the crank case to the required level, enable the excess to be drawn off through cocks. The governor, already described, is carried on the two-to-one secondary shaft.

The Pope-Toledo Motor.—The engine of the Pope-Toledo car is a good modern example of high compression motor. It is made in 2 and 4-cylinder models, developing, respectively, 14 and 24 horse-power at 900 revolutions. The end of perfect balance in each cylinder is attained by the use of a very long piston, carrying an additional expansion ring near its forward end, as shown in the sectional cut. Each cylinder is cast separate without a water jacket, that addition being supplied by a corrugated copper tube let over the outside circumference, being sweated and soldered in grooved flanges. The valve chambers are cast separate, forming a head-piece to the cylinder, which is bolted to the flanges. The lower end of the cylinder projects into the crank case, to which it is secured by flanges and bolts. The inlet valves are operated by suction and the exhaust from a two-to-one camshaft, after the usual plan. Special care is taken with every detail of this motor, mathematical refinements being continued even to the finishing of the piston rings by hand, all of which adds greatly to its efficiency and the ease of operation. According to test, this motor appears to be almost as noiseless as a steam machine.

Perfect balance and accurate adjustment are further advanced by the care expended in making the bearings. These are constructed from a special fomula of bronze and are cast in halves, accurately surfaced on a milling machine, soldered together, and the whole turned in a lathe so that the outer and inner surfaces

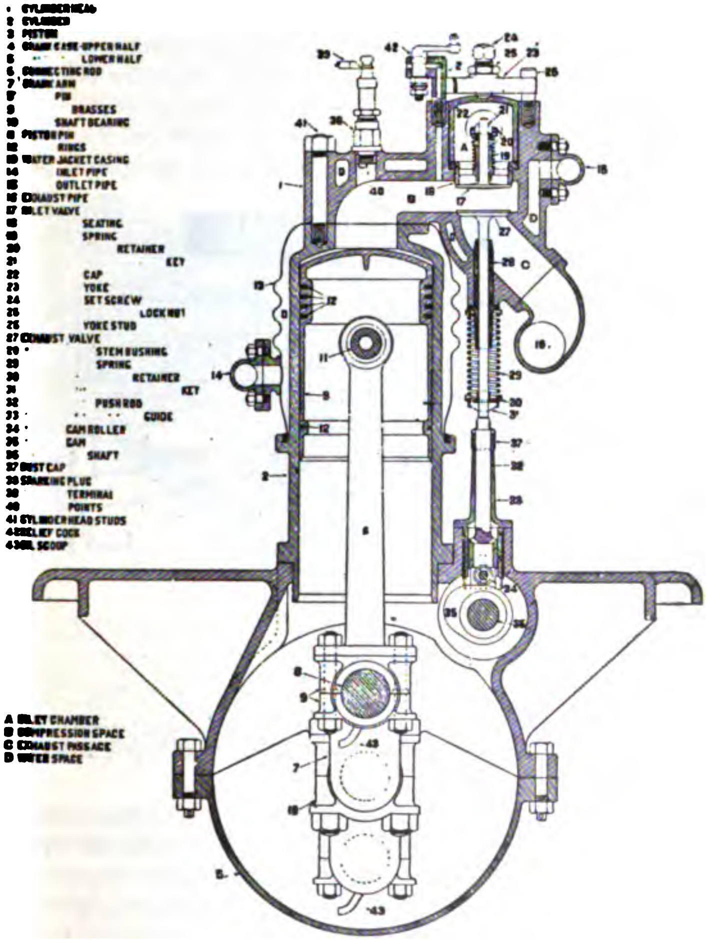


Fig. 245.—Section through one Cylinder of the Pope-Toledo Motor, showing parts and construction.

are perfectly true. At the conclusion of this rather complicated process they are carefully hand-surfaced.

The Opposed-Cylinder Motor.—The double-opposed cylinder engine may be said to be virtually an American development, although it was first designed and patented by Daimler in 1886, and was formerly used by Mors, Henroid, Gautier-Wehrlé and Turgan & Foy. It is very nearly the typical construction in America for double-cylinder motors not built on the lines laid down by Panhard-Levassor and other French designers. Builders who have adopted it declare that it is the type best adopted to maintaining good balance and overcoming vibration when two cylinders are used, as dispensing with the single-throw common crank, and giving, as nearly as possible, an even weight on both sides of the shaft. Probably the earliest American motor of this description is the well-known Haynes-Apperson, which has been a practical reality since the introduction of their carriages in 1893-94. So complete is the adjustment of the moving parts of this motor that noise and vibration are reduced to a minimum.

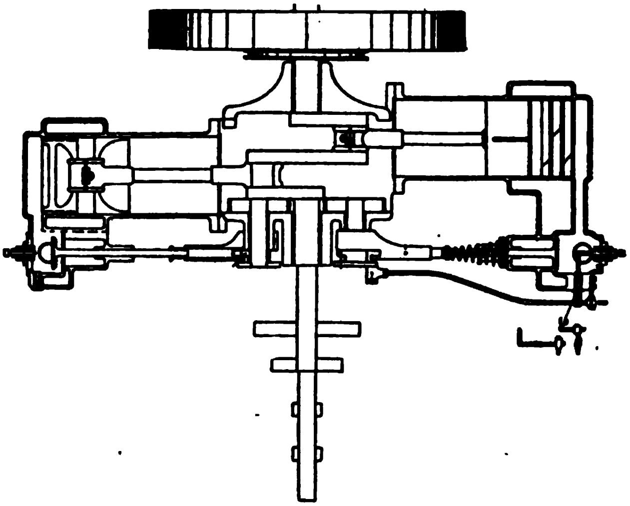


FIG. 246.—Sectional Diagram of the Haynes-Apperson, Double Opposed Cylinder Motor, showing valve arrangements and details of primary ignition device.

The manufacturers assert that one of their carriage motors has been connected to operate an electric light dynamo, and run without any perceptible variation in voltage, even when the connection is direct to the main shaft.

No attempt is made to control the speed of the engine by an automatic governor, the method employed being to throttle the charge, thus insuring only such proportionate mixtures as are required for the degree of speed or power desired. Two carburetters are employed, one for each cylinder. The operation of the throttle in each of them is to reduce the gasoline aperture to the required degree, both being operated by the same throttle lever, which connects to a button coming through the floor of the carriage under the driver's foot. The ignition is by a break-contact spark, the current being generated by a Holtzer-Cabot magneto. By throttling the charge the speed of the motor may be varied from 200 to 800 revolutions per minute.

FIG. 247.—Stevens-Duryea Motor—Pump Side. The spur-gear water force pump is driven by sprockets and chain from the crank shaft. The charge admission is throttled by moving the small sliding rod connected to the vertical lever seen at the right. This small rod, just below the mixture tube, reaching horizontally from one cylinder to the other, carries valve lift limiting wedges at each end, which permit greater or less rise of the automatic inlet valves, according to the wedge rod adjustment. The crank case cap is secured by wing nuts, and can be very quickly removed and replaced.

As shown in the photographic view, the cylinders and water jacket are cast in one piece, the headplates being bolted over a secure joint. The inlet valves are automatic, while the exhaust are operated from separate secondary camshafts, by which also the make-and-break of the electric sparking circuit is made by special rods, as shown in the section. As may be also seen, the inlet valves open at right angles to the exhaust.

The Stevens-Duryea Motor.—Another engine of the double opposed cylinder type is that used on the Stevens-Duryea carriage. It is in very many respects a masterpiece of design, and has shown high efficiency under operative conditions; combining lightness with power-capacity—the 7 horse-power engine weighs 125 pounds without the 75-pound flywheel, or 28.57 pounds per horse-power complete. As shown in the accompanying cuts, the cylinders are cast integral with their valve chambers, and are bolted to the aluminum crank chamber. The head plates are let into the bore and secured with four bolts.

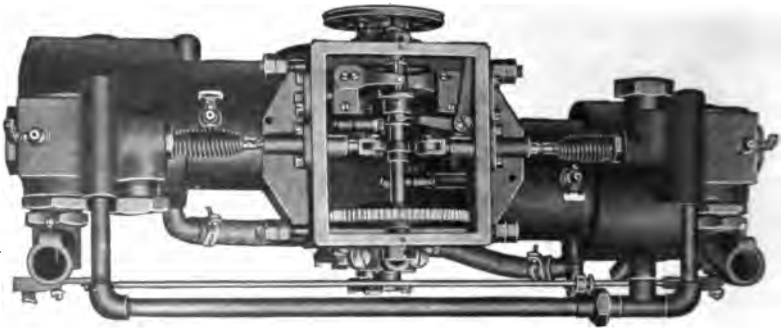


FIG. 248.—Stevens-Duryea Motor. Two opposed cylinders, working on cranks at 180 degrees. The crank shaft terminates in an integral disc to which the flywheel is secured by bolts in the outer circle of holes. while the change-gear shaft flange is secured by bolts in the inner circle of holes. Bore, 4¾ inches; stroke, 4½ inches; compression, about 50 pounds; jump-spark ignition, advanced by spiral slot in shifting hub; weight of motor, 125 pounds without flywheel; weight of wheel, 75 pounds; cast iron cylinders, alumimum crank box and cover, bronze plain bearing bushes in crank box, and bronze connecting rods; maximum R. P. M., 675.

Unlike the Haynes-Apperson motor, the Stevens-Duryea has the two cylinders duplicated, and so centred on the crank case as to allow both exhaust valves to be operated from a single cam at the centre of the camshaft. Instead of throttling the carburetter, charge, as with many other carriage motors, regulation is accomplished by an original device for controlling the opening of the inlet valves. A rod, connected between the valve chambers of the two cylinders and separated by a lever (shown in the cut) connected to the top of the single control lever, carries a wedge arrangement by which the lift of the valves may be progressively limited, thus controlling the amount of fuel mixture admitted to the combustion chamber at any stroke. As may be understood, both valves are simultaneously regulated as perfectly as possible. The water circulation is controlled by a centrifugal pump operated by chain and sprocket from the main shaft. At the opposite end of this shaft is a disc having two concentric circles of perforations, the outer for securing flywheel, the inner for securing the change-gear shaft, bolts being used in both instances. Ignition is by jump spark, the circuit breakers being situated on the two-to-one shaft, and the regulation of the spark being controlled from the driver's seat.

The most conspicuous fact connected with this motor is that the stroke is shorter in inches than the piston diameter; the ratio of the two being 19 to 18. The broad piston face yields a high-power surface, while the compression is moderate, being about 50 pounds. Seven horse-power may be developed at 675 revolutions.

The Ford Motor.—The Ford double-opposed cylinder motor is one of the few of this type having mechanically operated inlet valves. The crank box is covered by a plate, which supports a four-lead oiler operated by crank chamber pressure; this oiler is shown in working drawing detail. There is always a small pressure in crank chamber, and this is made to force the lubricating fluid through needle valves, which regulate a sight drop through individual glass tubes for each oil lead. The sight feed is used for making the original needle valve adjustment only for each lead. The cylinders are closed at the rear end, and the water jacket covers only the combustion chamber and valve seats. The second single motion shaft is driven by gearing from the crank shaft, both the admission and the exhaust valves being mechanically operated, only two cams being used. The ignition is by jump-spark, from two sets of batteries, one in reserve, carried in a box fixed to the plane.

The motor sits on a cross frame of its own, which carries the engine, piping, tanks and speed-change cam shaft all as an independent entirety, to be secured to the chassis frame by only four bolts, after the motor passes the testing floor. The motor piping is one straight mixture passage from the carburetter to both cylinders, and one straight exhaust pipe from both cylinders to the muffler.

Two of the copper oil-leads go to the cylinders, while the other two are carried to the crank shaft journals and the oiling function is carried out by establishing pressure in the crank chamber by the application of the starting crank to the motor shaft, and ceases when the crank chamber pressure is dissipated by the stoppage of the motor. This four-lead oiler is from original designs, and has a large capacity, giving four independently regulated lines of lubrication, besides being a great saver of lubricant.

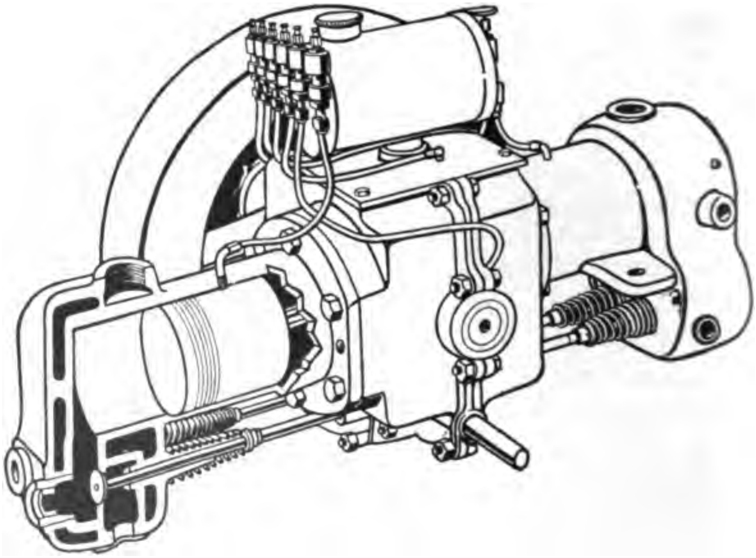


FIG. 249.—Section of the Ford Motor, showing positively operated inlet valves.

The fuel mixture volume regulation is by treadle and rod and bell crank and rod to the rocking vertical valve placed in the mixture passage from the carburetter to the cylinders The motor action responds to the fuel admission, and the spark advance regulation combined, or to either one singly, the intelligently combined operation or both being, of course, needful to high fuel economy.

The Duryea Three-Cylinder Motor.—As the pioneer of the three-cylinder carriage motor, the Duryea must be awarded a conspicuous position. The claims of its manufacturers—perfect balance of motion and the highest power-output per pound weight, while saving the added complication of a fourth cylinder with its necessary gearing—have been amply justified, not only by the records of the Duryea carriages, but also by the experiments of Panhard-Levassor and others, who have adopted this type of motor. The three cylinders are cast integral, with their water jackets and valve chambers, each having a 4½ inch bore and 4½ inch stroke, an output of 10½ B. H. P. being developed at 800 revolutions. The three water jackets are continuous, having common inlet and outlet ports. As will be seen from the sectional view, the jacket covers only the combustion space; the object being to cool only that portion of the cylinder exposed to the most intense heat of the combustion, leaving the remainder of the sweep uncooled in order that the temperature may be maintained at as high a point as possible during the expansion of the burned gases. The theory is that too much cooling is hostile to economy and efficiency, particularly at slow speeds, and much of

FIG. 250.—The Duryea Three-cylinder 10 1-2 B. H. P. Carriage Motor. A is the throttle slide, by which the gas supply to the three cylinders may be controlled by the combined steering and control lever shown in the last figure; B, single wire connecting anvils of the three sparking plugs in multiple, the other terminal of the circuit being connected to the middle parts of the cylinder; C, the common exhaust tube conveying the burned-out gases to the muffler; D, the pipe conveying air to the jackets of the three cylinders.

the wide range of speed of the Duryea motors result, it is claimed, from the fact that the gases are not thus condensed, but remain powerfully expansive to the end of the stroke.

The ignition is primary spark, the electric current being supplied by a magneto generator driven from the flywheel. One pole is grounded on the frame of the motor, while the current from the other is carried by two insulated anvils let into the walls of the combustion space. As shown in the sectional cut of the engine, a rocking contact-breaker or hammer, pivoted in the exhaust valve stem and caused to oscillate by a pawl extending over the camshaft, is lifted at the proper instant by a cam shaped for the purpose. The lifting of the pawl brings the sparker hammer into contact with the insulated anvil, completing the circuit. The sparker cam is abrupt on its rearward side, which permits the

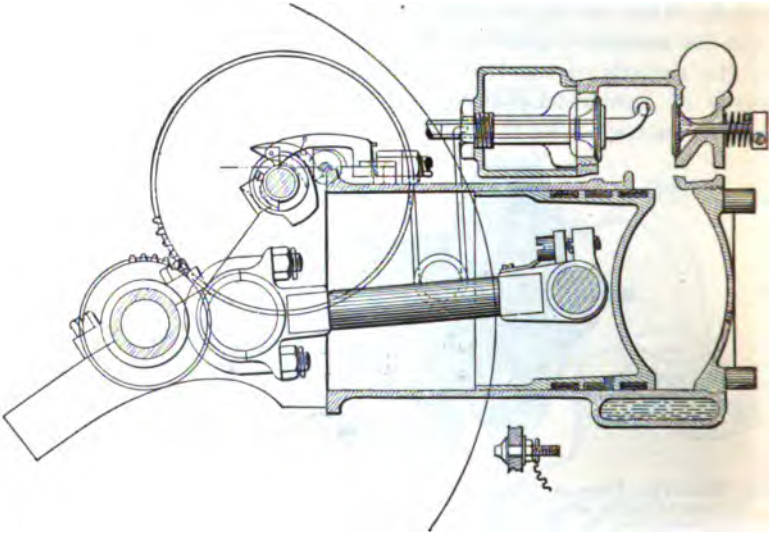


FIG. 251.—Sectional View through one Cylinder of the Duryea Carriage Motor, showing working parts. The exhaust cam operated by a two-to-one gear imparts a double motion to the valve pushrod; a lift for opening the valve, and a double twist for making and breaking the connections of the electrical spark. The valve and sparking chamber is projected so as to show the position of contained mechanism on a plane different from that of the cylinder section. Details of the insulated sparking anvil are shown below the cylinder. It is an iron contact point, having a mica washer on the inside and the outside of the cylinder walls, and a mica bushing between, so as to perfectly insulate it from the metal of the engine. A very short water jacket and the concave cylinder and piston heads are also exhibited in this figure.

pawl to drop instantly, making a sharp break and producing a strong, hot spark. The operation of the exhaust valve comes at a different time, so that the sparker operation is not interfered with, while removing the exhaust valve likewise removes the sparker hammer and permits inspection when needed. The insulated anvils are connected in muliple to the single wire, marked *B* on the accompanying cut. In other particulars, the electric arrangements are not different from the mechanical generator system long used on the Mors carriages.

The motor is operated without governing mechanism, the sole regulation being a single throttle slide, marked *A* in the accompanying view of the engine, by which the amount of opening of the inlet valves may be controlled.

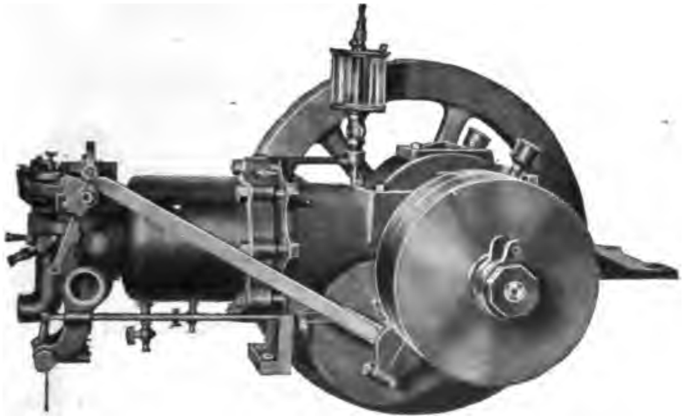


FIG. 252.—Side Elevation of the Cadillac Motor, showing connections for operating the valves and speed gear on the main shaft.

The Cadillac One-Cylinder Motor.—The single-cylinder motor of the Cadillac carriage embodies a number of features of exceptional interest. Its high power efficiency may be understood from the fact that with a piston diameter and stroke length each of five inches, it develops 6½ horse-power at 800 revolutions, and may be speeded up as high as 8¼. The cylinder is cast separate, the water-jacket being a copper sheath, shaped and flanged to be bolted over the wall, and the valve chambers arranged to be connected by a right-and-left screw joint to the head of the compression space. Both inlet and exhaust valves are positively operated—the former by a form of walking-beam from an eccentric, the latter by a bell-crank actuated by a push-rod, both from the two-to-one shaft. The eccentric rod, *C*, controlling the inlet valve, is not attached direct, but operates as a lever between two rollers, *G* and *S*, as shown in the sectional view. By means of the lever, *O*, connected by a link to the driver's hand,

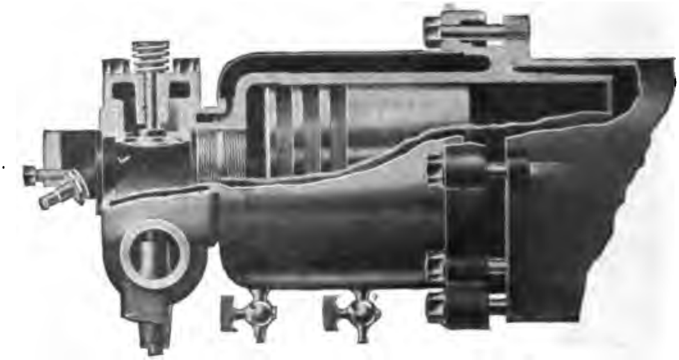


FIG. 253.—Part Section of the Cadillac Motor, showing position of valves and spark plug and the method of securing the copper jacket cover.

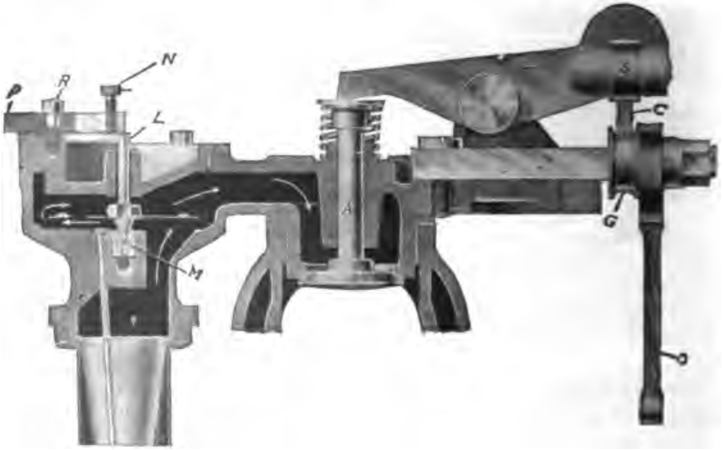


FIG. 254.—Carburetter and Intake Valve Mechanism of the Cadillac Motor. L is the gasoline valve; M, the gasoline inlet; N, the adjusting screw. A is the inlet valve; T, the walking-beam for opening it under positive impulse; C, the end of the eccentric rod, raising T by bearing on roller, S, with roller, G, as fulcrum. O is the handle by which the position of G, consequently the lift of the valve, A, may be varied as desired.

roller *G*, may be shifted backward or forward along the rod *C*, thus altering the position of the fulcrum, and, with it, the lift of the walking-beam, *T*, and the opening of the valve, *A*.

A notable feature of this engine is a peripheral groove around the junk ring between the two forward packing rings that connects with a longitudinal groove over the first ring. The object of the device is to encircle the piston with a ring of oil, ensuring perfect lubrication and utilizing all excess that might cause trouble by igniting.

This device may be understood by reference to Fig. 255, which shows two views of the piston (Figs. 1 and 2). In Fig. 1 (bottom of piston) the junk rings, *L*, *M* and *N*, and the first two packing rings, *A* and *B*, are grooved at *E* and *F*, forming a passage to the circular groove, *G*, which continues around the junk ring, *N*, connecting with the grooves, *H* and *K* (on top of the piston), Fig. 2, thus forming a passage past the third packing ring, *C*.

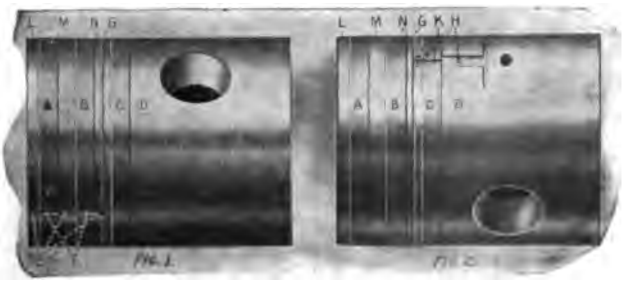


Fig. 255.—Diagrams showing Oil Groove Arrangement in the Cadillac Piston.

The result is, that any excess of oil on the lower part of the cylinder wall is forced into the circular groove around each side of the piston and out on the top, thereby encircling the piston with a ring of oil in the groove, *G*.

The passage is too small to produce any loss of power whatsoever, but maintains the most perfect lubrication possible at all points in the cylinder, using the oil that usually causes all kinds of trouble. By use of a convenient device, one key is arranged to make the battery circuit and to start the feed of oil under pressure.

The ignition is by jump-spark, the secondary circuit being conducted to the terminals of the double plug, already shown by insulated cables, not grounded, as usual circuits. The primary is grounded to the metal of the cylinder. A wipe contact commutator is used.

The carburetter used with this motor is shown in position in Fig 252, and in section in Fig. 254. Air is admitted through the vertical bent tube at the rear end of the cylinder, through a cone-shaped filter screen. Under suction of the piston, it causes the valve, *L*, to rise more or less from its seat by pressure against the wing flange carried on its rod, thus opening the gasoline passage, *M*, according as its lift is regulated by screw, *N*. Variations in the speed of the engine change the velocity of the incoming air current, and also the suction of gasoline at *M*, thus automatically regulating the amount of gasoline admitted with the air drawn into the tube.

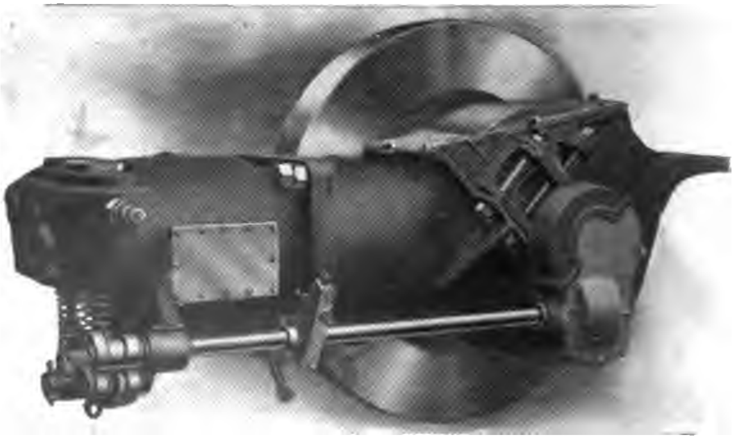


FIG. 256.—The Olds Carriage Motor.

The Olds Motor.—The motor used in the runabout is of the single-cylinder four-cycle type, having a 4½" bore and a 6" stroke, and developing about 4.7 horse power at 600 revolutions per minute. By a careful calculation of the weights of rotating and reciprocating parts, vibration has been reduced to a minimum. The transmission gear is carried direct upon one end of the main-shaft, just outside the flywheel, the other extremity carrying the circulating water pump, starting ratchet and spiral gear—this latter for actuating the cam shaft. This extends horizontally to the head of the motor, where it actuates a rocking cam which engages both the inlet and exhaust valve stems, these projecting below the motor head. The make-and-break contact for the jump-spark ignition apparatus is also on the cam shaft, being disposed just back of the worm gear which drives it.

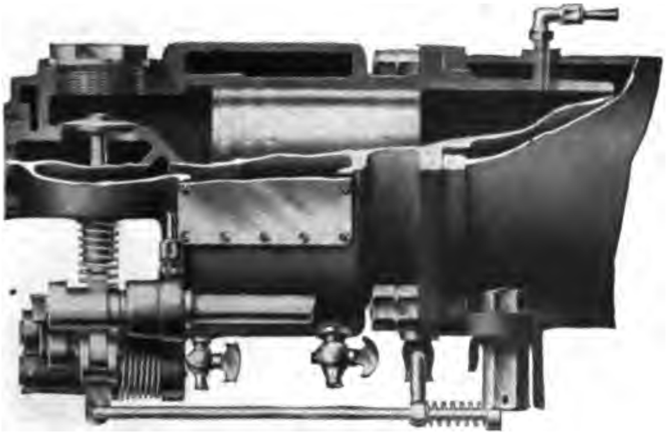


FIG. 257.—Part Sectional View of the Olds Motor, showing valve-operating mechanism.

FIG. 257a.—Connecting Rod of the Olds Motor, showing heavy construction.

The Fuel Supply is drawn direct from fuel tank into removable sediment cup or vaporizer; all impurities being deposited, passes through vertical tube and regulating needle valve to spraying nozzle. Flow determined by a valve opening against gravity by suction in the motor cylinder. A light collar or flange upon the stem aids in lifting the valve and in spraying the gasoline in the path of the inrushing air, which, like the gas, is under control by means of a sliding gate with a slot just wide enough to permit of movement backward and forward across the air passage. A priming device, a small brass piece sliding on the nozzle, may be lifted closing the gate valve opening, compelling all air to pass through vertical holes drilled through it, so as to strike the flange on the needle valve spindle, lifting it from its seat. Thus the flow of gasoline is kept normal, in spite of slow suction when cranking the engine.

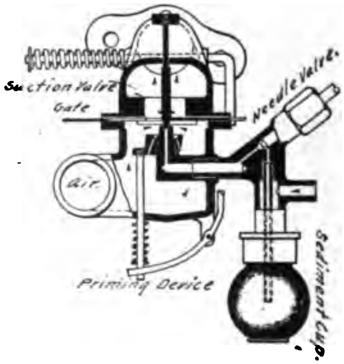


FIG. 258.—The Olds Mixer, with parts designated.

CHAPTER TWENTY-THREE.

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THE CONSTRUCTION AND CONTROL OF TYPICAL GASOLINE CARRIAGES.

Daimler's Early Motor Carriages.—The first application of the Daimler motor to the work of propelling road vehicles was made in 1885, when Daimler built the motor bicycle, or velocipede, shown in an accompanying illustration. The motor was hung between the wheels from a heavy iron framework, and directly above it was the seat. Just below the motor, and connected to the platform on which it rested, were two auxiliary rollers or small wheels, which could be drawn up or lowered by the pressure of the driver's foot on a pedal. The object of these rollers was to afford a support for the vehicle when the motor was not in operation.

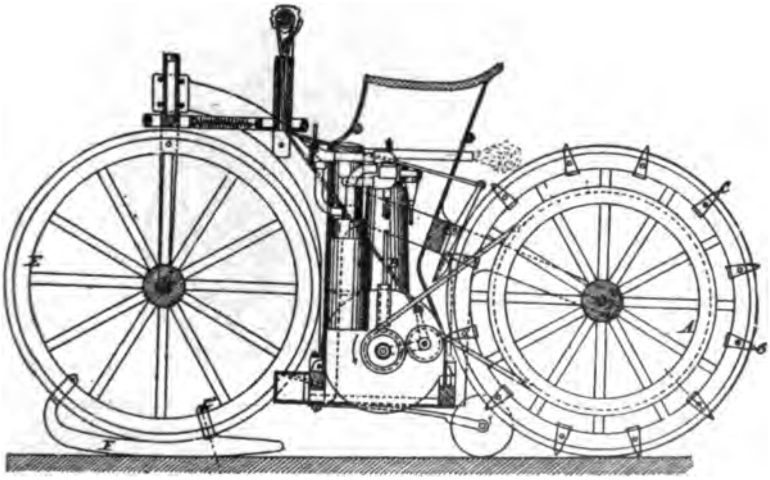


FIG. 259.—Sketch of Daimler's First Gasoline Propelled Bicycle. This machine is shown arranged for sliding on ice, having teeth, C, in the rear wheel, and the runner, F, secured to the forward wheel, E. A is the driving pulley on the rear wheel; B, the cylinder of the motor.

On the earliest bicycle of this type, which saw its first successful trial on November 10, 1885, the driving was by a belt from a pulley carried on the crank-shaft to another one of larger diameter, attached to the rear wheel. The motor was started by pushing the bicycle in the usual manner, and the power was thrown in or out by drawing up the jockey pulley, thus tightening the belt. While there were no provisions on this bicycle for varying the speed during travel, it was possible to shift the belt between two pulleys of different diameter attached to the driving-wheel, thus securing some slight variation.

The earliest four-wheeled vehicle was propelled by a Daimler upright single-cylinder engine, such as has already been described. The connections and manner of shifting the jockey pulley or idler, used for tightening the belt, are shown in the detailed cut of the motor. The belt transmission used on the early bicycles is practically the device used on Daimler's motor carriages for a number of years. As a matter of fact, numerous writers speak of this form of transmission as a typical feature.

FIG. 260.—The First Daimler Motor Carriage. The motor was connected to the driving axle by two belts; one for high speed, the other for climbing; either being thrown into action as the belts were tightened by jockey pulleys, as shown in Fig. 261. Both could be thrown out of action to stop the carriage without stopping the motor. The forward axle of this carriage was centre-pivoted and turned on a fifth wheel, as in horse carriages; the steering being by upright pillar rising before the driver's seat.

The earliest four-wheeled vehicle propelled by a Daimler motor was built in 1886. It seems to have been a modified horse carriage, having the forward axle turned by an upright steering pillar and hand-wheel, and with driving pulleys geared to each of the rear wheels. As shown in an illustration, which was reproduced from a German book, a motor of the same general type as that used on the bicycles was placed behind the forward seat, and imparted its power direct from the main shaft to the driving pulleys on the rear wheels.

The Daimler Belt and Pulley Transmission.—The belt transmission, used with the earlier Daimler carriages consisted of

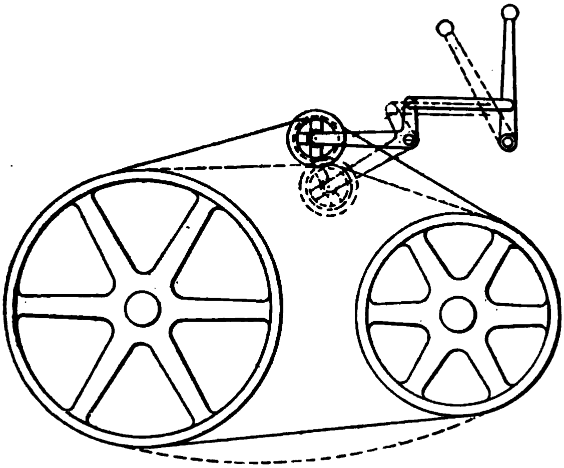


FIG. 261.—Diagram of the Belt Transmission, used on the early Daimler carriages. As shown in the cut, two pulleys of different diameters—any diameter ratios may be used—are connected by a belt. This belt is normally loose, but may be tightened by a jockey pulley mounted on one arm of a bell crank lever, so as to tighten or loosen the belt, according to the position given it by the hand lever, as indicated by the full and dotted lines.

four pulleys regularly increasing in size, keyed to the main shaft, and four others regularly decreasing in size in the same order, keyed to the countershaft. Four belts connected these eight pulleys, and the power was thrown upon any one pair as desired, by tightening the belt with an idler pulley mounted on a suitably disposed bell crank. By this method it was possible to obtain four speeds forward on an even roadway, or to vary the power in ascending grades. There was no provision, however, for reversing, the only method of turning the carriage in a short radius being to bring the centre pivoted front axle all the way around, so that the small forward wheel cut under the body, as in a horse-drawn vehicle. It might have been possible to re-

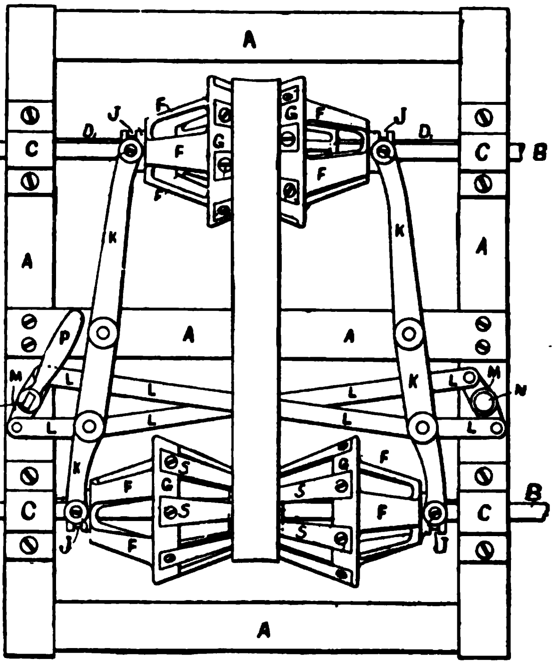


FIG. 262.—Diagram of a Variable Cone Pulley Transmission, by which the relative speeds of the driving shaft and countershaft may be varied by changing the diameters of the driving and driven pulleys. In this figure, A is a frame on which are mounted two shafts, B and B, turning in the bearings, C and C. On each of these shafts is a feather, D, on which slide double cones, F, F, F, F. To the apex, J, of each of these cones, are attached fingers, S, S, S, S, which are screwed to the heads, G, G, G, G, as shown. A handle, P, pivoted at N, may be turned in either direction, actuating the levers, L, L, L, L and K, K, K, K; thus modifying the belted diameter of either pulley from that shown in the upper of the two to that shown in the lower one. Thus the speed ratios in the two may be varied to any desired point. The levers, K, K, K, K, by forked connections, actuate the cones, causing them to slide along the feathers, D, D, D, D, at the spools, J, J, J, J. The device shown in this illustration is the subject of an American patent; but similarly arranged and operated cone pulleys have been employed on the Fouillarion carriage and others.

verse by simply crossing one of the belts, although it is doubtful if a cross belt, unless of unusual length, could be tightened with an idler pulley. A loose pulley on both shafts of a belt-shifter would seem to furnish the only really practical device. Fast and loose pulleys with shifting belts have been successfully applied in several types of motor vehicle, notably on some of the light Benz carriages made in Germany, and one or two of those manufactured by the English Daimler Motor Co. In both these instances, however, the shafts are arranged at a sufficient distance between centres to enable an easy shifting of the belts.

Typical Transmission Systems.—Although, as shown in the foregoing cuts of the early Daimler carriages, the original plan of transmission was to belt the main shaft to a secondary carrying a spur gear to drive the road wheels, the belt and chain drive soon became the prevailing type. This was true even with the Mors carriages having the motor hung to the rear axle. The early Valeé carriages were driven by a belt direct from the main motor shaft to the rear axle, the speed being varied solely by throttling, without the use of speed-changers of any kind. This involved the use of an extra high powered engine. The Darracq-Bollée had a stepped cone pulley arrangement in which the belt was shifted by a special belt-shipper, as in lathes and other shop machinery, while several other cars had only the Daimler belt tranmission already described. The belt, however, fell into disuse on the best makes of car, the tendency being steadily toward chain or bevel gear transmissions. Virtually, only one notable car uses the belt at the present time, and that is the Fouillarion, whose speed-changer is the variable pulley shown on the opposite page. As regards direct bevel gear drive to the differential, that was probably introduced on the Darracq carriages, by which it is still used. This arrangement has the advantage of a firm, steady drive, saving most of the power that is inevitably lost in chain-driving. Some builders object to it, however, on the ground of the extra wear and looseness that follows on long use, although, as seems probable, this difficulty may be largely overrated.

Countershaft and Dead Axle Transmissions.—At the present day the typical French transmission is to drive from the main shaft, through the speed gear to a countershaft set across the width of the carriage. Sprocket and chain connection from either extremity of this secondary shaft to both road wheels, turning on a dead axle, drives the carriage. This arrangement is shown in the plan view of the Panhard six horse-power carriage. The prevailing plan in American carriages, until within a very few years, has been to drive direct from the main shaft, or a secondary, carrying the speed gear, by chain and sprocket to the differential on a live rear axle.

The Work of Panhard-Levassor and Others.—One of the most important chapters in the history of gasoline motor-vehicle development is to be found in the work of the French firm of Panhard & Levassor, whose name is still regarded as among the foremost in the automobile world. This firm was originally a manufacturer of various kinds of industrial machinery, and brought to the manufacture of motor vehicles a long experience and a well-equipped plant. Evidently foreseeing the possibilities of the Daimler engine and carriage, they, in 1890, secured the French rights to manufacture both. Thereafter, for several years, other French manufacturers of motor vehicles using the Daimler motors were obliged to obtain their engines from Panhard-Levassor.

Not only are the Panhard vehicles notable from the fact that they were among the earliest successful carriages, but also because, owing to the vast skill and experience of their manufacturers, they embodied principles of design which are recognized as the most excellent for motor carriage purposes, and some of which must certainly continue permanent. Among these excellent elements of construction may be mentioned the fact that from the start they adopted a wooden underframe, at first sheathed with angle-iron, later consisting of wooden bars, and at no time in the development of their vehicles did they waste time and ingenuity on the steel tubular framework, which many manufacturers still seem to consider essential for securing the combined ends of strength and lightness. Among the earliest known examples of steel tubular construction was the Peugeot-Daimler carriage of 1895.

The general designs of Panhard-Levassor were adopted by the English Daimler Motor Co., and also had a great effect on the subsequent construction of the German manufacturers. The eraliest types of their carriages, as also manufactured by Peugeot Brothers and the English Daimler Motor Co., were equipped with the famous V-shaped Daimler engine, which was, however,

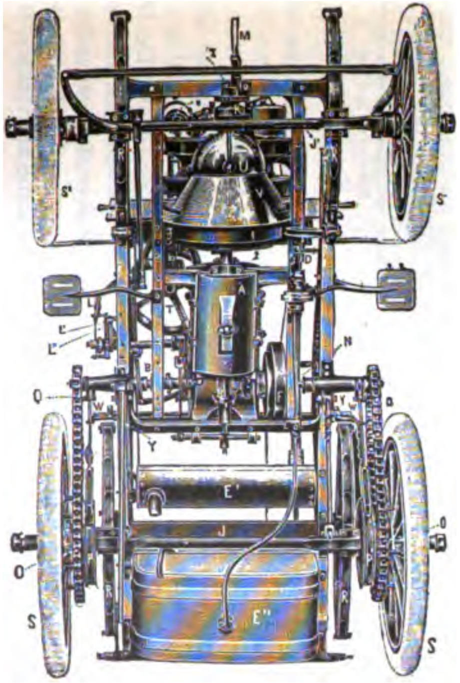


FIG. 263 (from above).

FIGS. 263 and 264.—Plan of the body and underframe of the six horse-power Panhard-Levassor Carriage, showing machinery and general apparatus in position. A is the case containing the change speed gear; B, the reversing connections; C, the carburetter; D, the circulation pump; E, gasoline tank; E', the muffler; E'', the water reservoir; F, the differential gear case; H, oil pump; H', adjustable oil cup; J, rear axle; J', forward axle; L, the braking lever; L', reversing lever; L'', speed changing lever; M, starting crank; O, the sprocket on the rear wheels; P, the brake drums on the rear wheels; Q, the driving chain; S, the rear wheels; S', the forward wheels; T, the steering gear; U, the motor case; V, the case enclosing the flywheel and main clutch; W, the attachment for controlling the brakes; Y, the adjustable distance rod between the carriage body and the rear wheels; P and P, drums for the band brake; (1), female cone of the main clutch; (2), male cone of the main clutch.

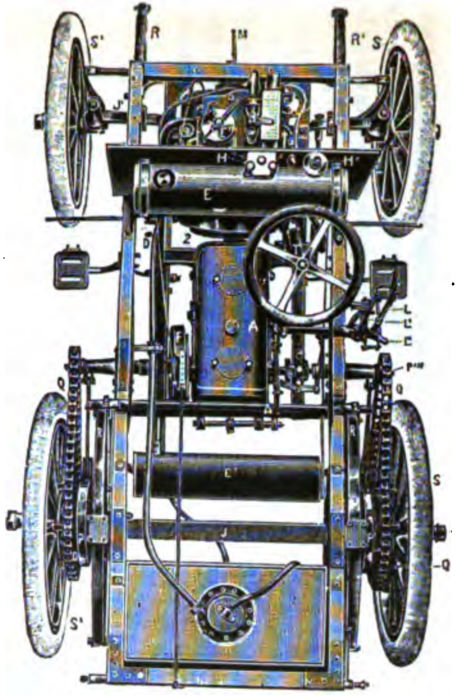


FIG. 264 (from below).

of not more than 6 H. P. Very early in the development of their carriages, also, this firm devised and constructed the speed-changing gear, which will be described on a later page under their name. A very similar structure was used on the Peugeot carriages, the principal difference lying in the fact that the reverse motion was accomplished by throwing into gear an extra spur-wheel or idler, which was of sufficient length along its spindle to connect together two spurs on the interacting shafts, apart from the ordinary process of shifting. The latter description of gear is the same in general principles as was used on some of the later cars constructed by the Cannstadt-Daimler Co.

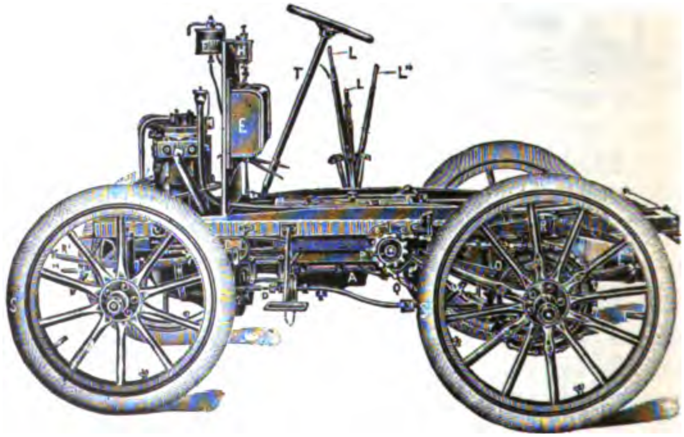


FIG. 265.—Side Elevation of the Panhard-Levassor Six-horse-power Carriage. A, the transmission gear case; E, the gasoline tank; H, oil pump; L. lever for throwing out clutch; L′, reversing lever; L″, change-speed lever; M, starting crank; O, rear wheel sprocket; P‴, sprocket pinion on jack shaft; Q, driving chain; S, rear wheel; S′, forward wheel; T, the steering wheel and pillar; R, rear spring; R′, forward spring; 1, male cone; 2, female cone.

Another structural feature of the Panhard carriages was, following along the now accepted Daimler lines, the placing of the motor over the forward wheels and covering it by a sloping fore-structure or bonnet. With the Peugeots, Benz, Mors, De Dion, and several other well-known designers and builders, the usual plan was from the start to hang the motor over the rear axle, and some of the earlier carriage constructions resulted in so overloading the rear wheels, that, according to some authorities, steering was rendered difficult. As the science of vehicle construction developed, however, this difficulty was fully overcome, and it is now a well-accepted principle of construction that, while the bulk of the weight should rest over the rear axle, the forward axle should also bear a large part of the load.

The Panhard Control System.—The Panhard-Levassor carriage shown in accompanying cuts is typical of the arrangements still used by its manufacturers, although in the various models now made a number of changes will be discovered. Whether constructed with 2, 3 or 4 cylinders, the motor is placed over the forward axle, and transmits its power through a longitudinal shaft and a cone clutch to the change-speed gear. Here the rotation is transferred by bevels, as shown in the cuts, to the differential drum on the transverse countershaft. As the details of the motor, change-speed gear and steering connections of this make of vehicle have already been explained, we may proceed to examine the method of control here employed. There are three levers, marked respectively L, L′, L″, by which all the necessary functions beside steering—and in later models throttling and spark controlling—may be perfectly performed. As may be readily understood, the operation of the transmission gear of this car, as shown in Fig. 266, requires three separate levers—the one for setting and releasing the clutch marked *E* (*L*) in that figure, the second *D* (*L″*), for sliding the gears upon the square shaft *A*, and the third (*L′*) for shifting either of the bevels *H* or *L*, in or out of gear with bevel *G*, carried on the end of secondary shaft *C*, thus affording means for reversing the movement of the carriage. The clutch lever, *E* (*L*), if carried back sufficiently far, after throwing out the clutch, will set the hub brakes, thus performing these two necessarily consecutive functions by one act of the chauffeur.

The Panhard-Levassor Speed Gears.—The sliding gear transmission and reversing mechanism used on the earlier Panhard carriages is shown in an accompanying figure. It consists of two shafts, *A* and *C*, the former carrying on its square portion the sleeve, *B*, upon which are four spur gears of varying diameter. On the shaft, *C*, are keyed four gears, whose diameters vary inversely with those on *A*. At the right-hand extremity of the shaft, *A*, is carried the male cone of the main clutch, which, when held in gear by a pressure of the spring, *F*, enables the transmission of power direct from the crank to the shaft, *A*. The clutch may be thrown out by lever, *E*, which acts to pull the shaft, *A*, to the left, compressing the spring, *F*. The sleeve, *B*, may be shifted on the main shaft by lever, *D*, which is connected as indicated. When, as in the cut, the gear, B^1, is meshed with the gear, C^1, the car will have its slowest speed forward, and the act of shifting the gears to the left from that position will raise the

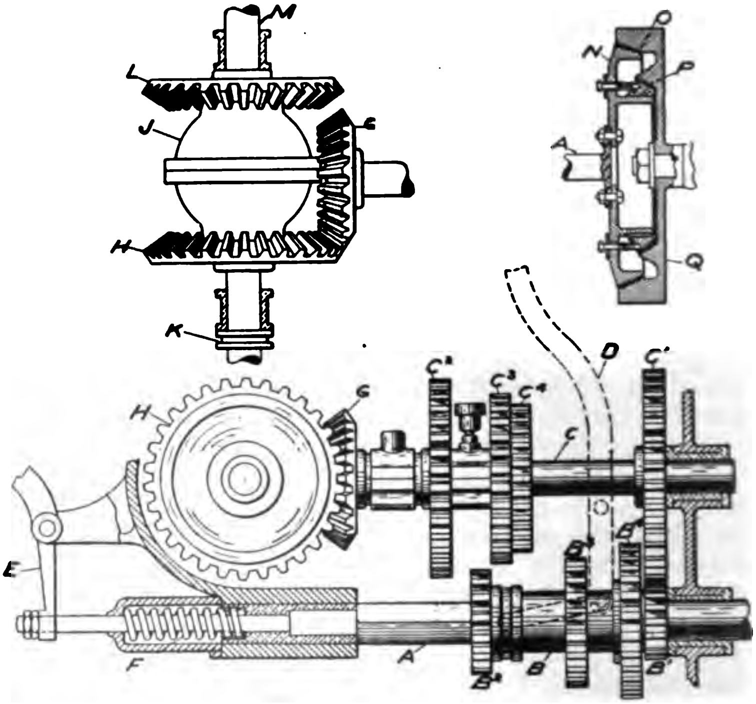


FIG. 266.—Details of the Panhard-Levassor Change Speed Gear. A is a square section of the main driving shaft; B is a sleeve caused to slide on A by means of lever, D, which carries four spur pinions, B^1, B^2, B^3, B^4, of such diameter as to mesh with pinions, C^1, C^2, C^3, C^4, keyed on the countershaft, C; the motion being imparted from the main shaft, A, through sleeve, B, through any one pair of pinions to the shaft, C, causing the rotation of the bevel pinion, G. Gears, H and L, are secured to a sleeve sliding on a feather on shaft, M. J is a differential gear drum. The main clutch is thrown on or off by means of the lever, E, and is held in position by the spring, F.

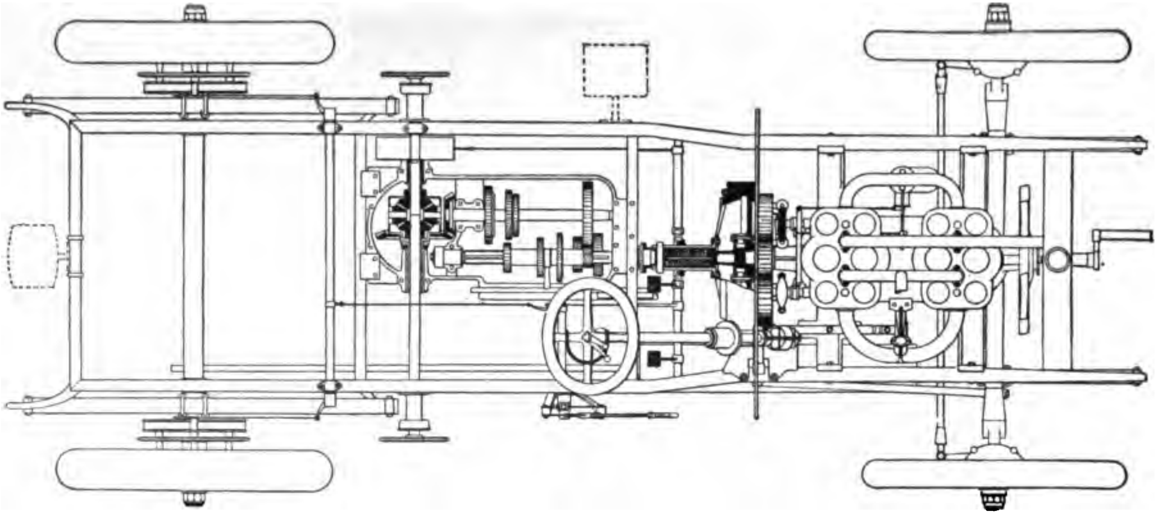


Fig. 267.—Chassis of the Smith-Mabley Simplex Touring Car, an American-built gasoline vehicle, built after Panhard models. This car is typical of many of the best points of French designs. The motor has four cylinders, all valves being positively operated. The improved Panhard transmission gear is used, its connection to a single bevel on the differential drum being shown. The main brake drum is set on a sleeve to which the differential is also attached.

speed at a regularly increasing ratio; the meshing of B^2 and C^2, giving the second speed forward, and the other gears the next two increasing speeds. Similarly, also, in the act of shifting the sleeve from the extreme left position, when gear, B^4, is meshed with gear, C^4, there will be a similarly regular decrease of ratio in their speed.

The motion is transmitted from shaft, *C*, through the bevel gear, *G*, which, as shown in both sections of the cut, meshes with another bevel on the transverse jack shaft. This bevel, *H*, and a similar bevel, *L*, on the case containing the differential gear, are keyed to the sleeve, *M*, which works over the centre-divided countershaft, at two extremities of which are the sprocket pinions for driving direct to each of the rear wheels. As long as the bevel, *G*, drives on *H*, as shown, the motion of the carriage is forward, at any speed determined by the relative position of the

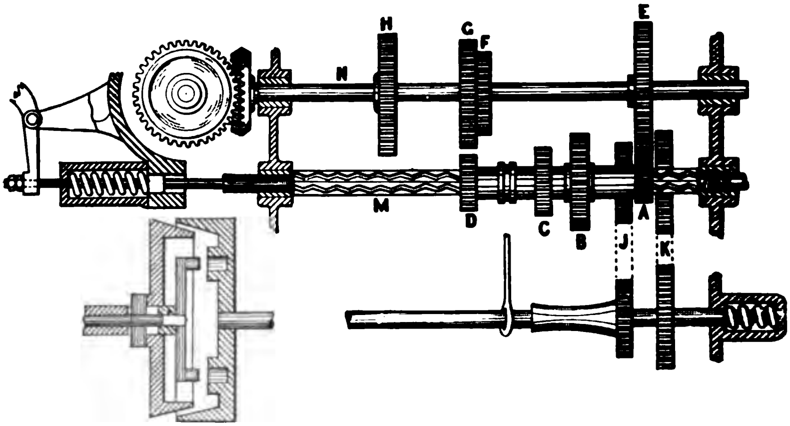


Fig. 268.—Sketch of the Improved Panhard-Levassor Transmission and Clutch. Here, M is the square portion of the clutch shaft, and N the driving, or top, shaft, carrying a bevel pinion meshing with another single bevel on the transverse jack shaft. A, B, C, D, on the sleeve mesh with E, F, G, H, on N. J and K are gears keyed on a third shaft parallel with M, shown projected at the base of the cut. When the sleeve-carrying gears, A, B, C, D, is slid all the way forward (to the right) the third shaft is moved endwise against a coiled spring, causing K to mesh with A and J with E, thus reversing the motion of the carriage. The clutch is shown sketched at the left of the cut. Here the male cone is normally held in by a feather on the end of a shaft sliding in a longitudinal bore in the main shaft, under pressure of a spring. This inner shaft also carries on its end a two-armed spider with pins to fit into holes, as shown, thus enforcing the twisting resistance of the cone.

shifting gears on the two shafts, *B* and *C*. In order to reverse the motion of the carriage, the sleeve, *M*, is shifted upon the lever, acting on the spool, *K*, so that *H* is pushed out of mesh with *G*, and *L* is thrown in. By this process, as is obvious although the rotation of *G* continues in the same direction, the movement imparted to *L* will be the reverse of that previously imparted to *H*. Thus the reverse has the same number of speed and power combinations as the forward motion. It is also obvious that, by shifting the sleeve, *M*, a certain distance, the driving connections to the main shaft, through the differential, *J*, will be thrown off altogether. This is the operation necessarily preceding the throwing on of the brake, the drum of which is on the countershaft, just beyond the thimble, *H*.

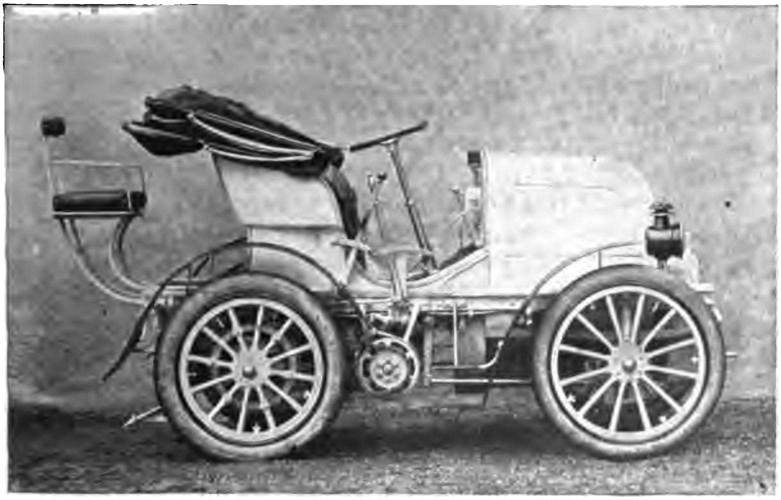


Fig. 269.—Two-seated Pleasure Carriage for General Use. Built by the Cannstadt-Daimler Co.

On the later models of Panhard carriages a simplified variation of this transmission gear is used, which drives through a single bevel gear on the jack shaft, constantly in mesh with the bevel on the secondary driven shaft, or top shaft,—thus requiring no shifting of the differential to throw in the reverse bevel. A third shaft, set parallel to the clutch shaft, carries two spur gears, as shown in the diagram. The great advantage of this arrangement is that the four forward speeds and reverse may be operated with a single lever, which may be thrown progressively forward for each forward speed and brought all the way back for the reverse. The manner of operation is simple. The shifting lever operates a rod sliding parallel to the three shafts, and from it extends an arm that engages the spool on the sliding sleeve, and also slides along the reversing shaft. At the position shown in the diagram the lowest forward speed is engaged, through the meshing of the spurs, *A* and *E*. By bringing the hand lever all the way back, the sleeve is moved clear to the right, and *A* and *E* are thrown out of mesh. At the same time, the arm of the sliding gear shifter meets a raised portion of the reverse shaft, as shown, and pushes it to the right, depressing the spring. The spur, *J*, is then meshed with *E*, and *K* with *E*—the movement of the main clutch shaft being thus transmitted to the top shaft through the engagement and rotation of the third, or reverse, shaft.

The Daimler Transmission and Control.—The Cannstadt-Daimler carriage performs these four functions by the use of only two levers—the one for controlling the clutch, changing the speed and reversing the direction of travel; the other for setting and releasing the brakes. In the accompanying representation of this carriage, the common clutch and speed lever is seen beside the seat to the rear of and crossing the brake lever set forward directly over the driving sprocket on the end of the transverse countershaft. The method of operating the common change-speed and reversing lever is found in the use of a double H-shaped slot, or grid sector, so that the lever may be moved backward or forward in any one of three parallel channels, or shifted sideways from one to another by means of a fourth channel cut at right angles to the other three, like the cross line of the letter H.

The theory and operation are simple. The hand lever is pivoted to a cross spindle, which may be slid lengthwise in its bearings whenever the hand lever is brought to the middle transverse slot of the grid sector, thus providing the necessary first principles for operating the apparatus. The four speed and reverse gear is of the sliding spur pattern, like the Panhard-Levassor already described, except for the fact that the four sliding spurs on the square section of the main shaft are in two sections of two spurs each. Each section is shifted by an arm projecting downward from a horizontal rod bearing a rack on the outer end. Furthermore, these two rack rods are set side by side, so that a toothed sector on the lower extremity of the hand lever may engage either one of the racks, operating either of the two lower speeds when the lever is moving in the left-hand slot, and either of the two higher speeds when it is moving in the second slot. When drawn to the backward position in either slot, it operates the lower of the two speeds, and, in the forward position, the higher of the two. In order to reverse the movement of the carriage, the hand lever is brought to the mid-position on the grid-sector, shifted all the way to the right, and moved forward. This operation is possible because the cross spindle to which the lever is pivoted carries an

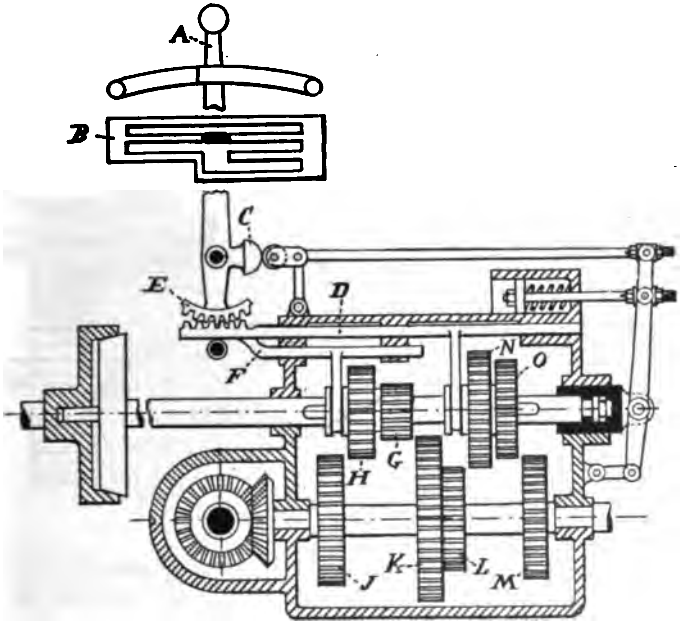


Fig. 270.—Transmission Gear of the Cannstadt-Daimler Carriage shown in the last figure. Here, A is the hand lever; B, the gridiron quadrant; C, a dog on the lever for throwing out the clutch in shifting the gears; E, toothed sector at end of A for actuating rack rods D and F (see next figure); G and H, low-speed gears on the clutch shaft; J and K, low-speed gears on the second, or driving, shaft; N and O, high-speed gears on the clutch shaft; L and M, high-speed gears on the second shaft. H and G are shifted on square portion of shaft by rack, F; N and O by rack, D.

arm projecting downward at right angles, and terminating in another toothed sector that, when the lever is slid over to the right, as just explained, engages a third rack bar geared to throw in the reverse pinion, *B* (Fig. 271). The arm, *K*, in the same figure, carries an upward turned slot in a position to engage a pin on the reverse rack-shaft, so that, when that shaft is slid forward by the interworking of the rack and sector, the arm is lifted and pinion *B* brought into position by the operation of a bell-crank. In addition to the toothed sector set at its lower extremity, the hand lever has an arm at right angles exactly at the pivotal point, so that, when the lever is brought to the transverse slot of the grid-sector, this arm presses upon a bar, thus throwing out the clutch. The advantage of this arrangement is that the clutch may be thrown out before the gears are shifted, without the use of a separate lever or any locking device to prevent shifting of speed before the clutch is out. It has the disadvantage, however, that the clutch is nominally on, which involves that a certain amount of strength should be required to operate the lever, and thus prevent inopportune starting of the carriage.

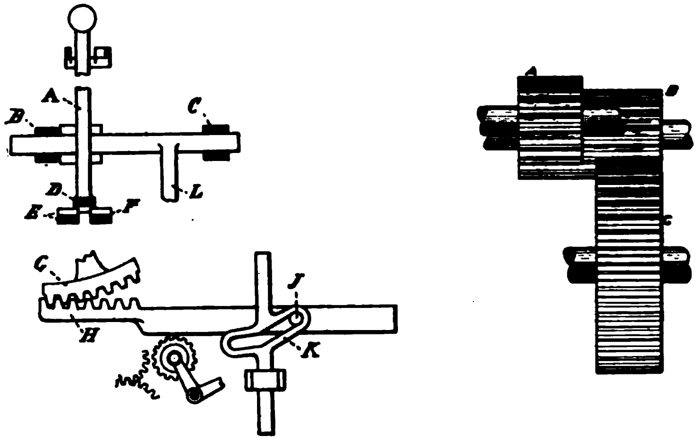


FIG. 271.—Details of Side-shifting Change Lever of the Cannstadt-Daimler Car. A is the lever, pivoted between bearings, B and C. D is the toothed sector, which may be shifted to engage either of the rack rods, E or F; L is a downward extension from the pivot rod of A, carrying the sector, G, which may be slid into mesh with rack, H. By sliding rack, H, to the right, as in the cut, pin, J, lifts the rod attached to the curved slot, K, throwing in the reverse pinion. The manner of doing this is shown with the pinions, A and C, meshing with the long reverse pinion, B.

The Decauville Carriage.—Next to the Panhard-Levassor, the French carriage best known in America, is probably the Decauville. It combines a number of excellent features, which insure strength of construction and ease of operation. Like many other prominent automobiles, its under frame is composed of solid angle-steel, to which the front and rear axles are hung by springs. The drive is by bevel gear to the differential drum, and the two portions of the divided rear axle turn in sleeves, which are solidly bolted to the differential case and supported by struts at either side. The construction of the running gear is rendered still more substantial by a solid-pressed steel pan hung upon the frame, and so shaped as to afford perfect support for the motor and transmission gear case. This arrangement involves the further advantage of providing a perfectly rigid connection between motor and transmission when the clutch is on.

FIG. 272.—Decauville Four-cylinder Car, with Plain Tonneau Body.

The Motor and Sparking Apparatus.—The 1904 models of Decauville cars include one two-cylinder, 4.29x4.29 inches, 12 to 15 horse power, and four four-cylinder models—3.5x4.29 inches, 12 to 16 horse power; 3.7x4.29 inches, 16 to 18 horse power; 3.9x4.29 inches, 18 to 24 horse power; 5.46x6.43 inches, 40 to 50 horse power. The first model has a speed range of between 8 and 34 miles per hour, the others have a maximum speed range of between 35 and 70. Like other typical French motors at the present day, the inlet valves are mechanically operated from a two-to-one shaft on the opposite sides of the cylinders

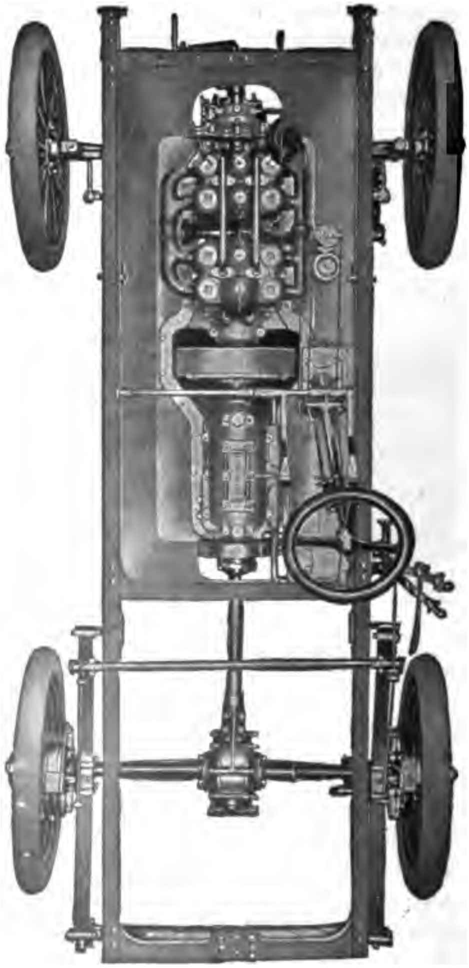
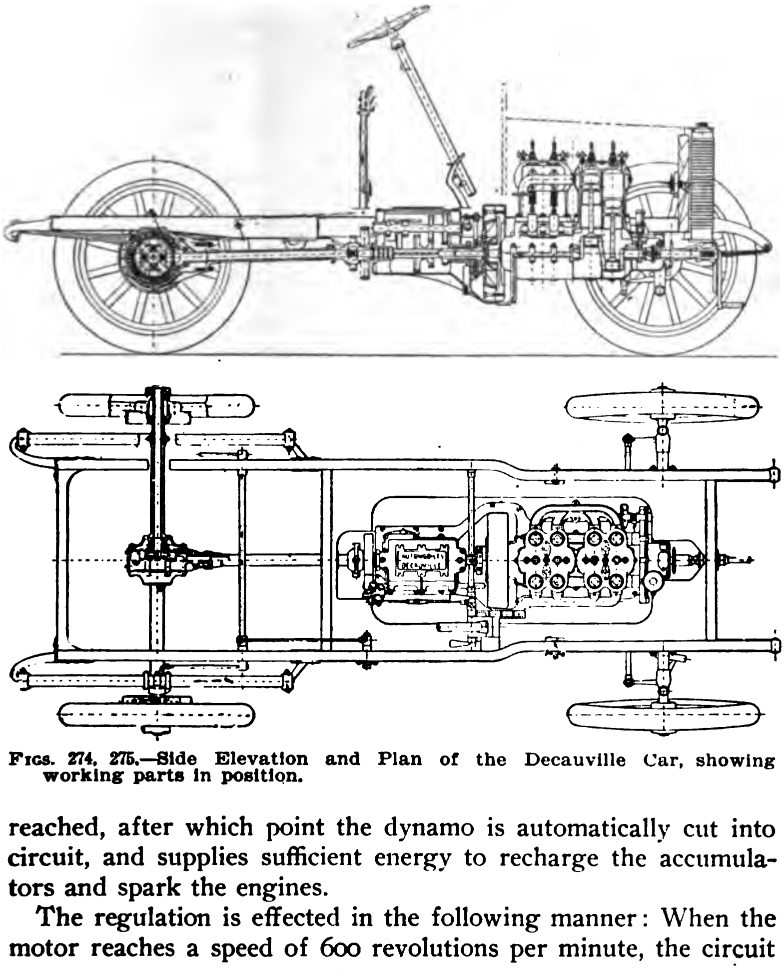


Fig. 273.—Plan View of Chassis of the Decauville Car, showing motor and transmission in the steel pan secured to the frame.

from the exhausts. Ignition is by jump-spark, which may be advanced or retarded, on the commutator by a handle operating a rod set at one side of the steering pillar. The intake volume is regulated by an automatic governor, and may also be controlled by a handle at the steering pillar.

Current for ignition is supplied at the start by storage batteries, which continue the supply until a speed of 600 revolutions is reached, after which point the dynamo is automatically cut into circuit, and supplies sufficient energy to recharge the accumulators and spark the engines.



Figs. 274, 275.—Side Elevation and Plan of the Decauville Car, showing working parts in position.

The regulation is effected in the following manner: When the motor reaches a speed of 600 revolutions per minute, the circuit

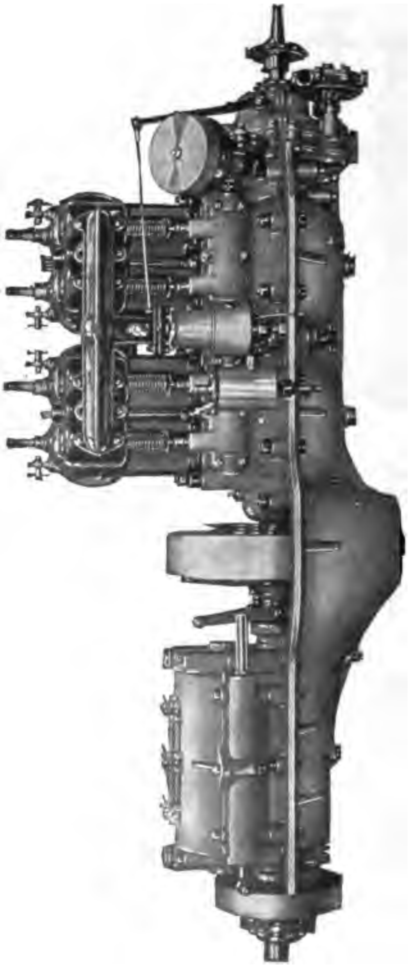


FIG. 276.—View of Engine and Gear Box of the Decauville Car, showing one-piece steel bottom casting, making it impossible for the shafts to get out of alignment.

breaker cuts the dynamo into the circuit; from this speed upward, the output of the dynamo remains practically constant, by means of the special winding employed. There is consequently no particular precaution to be observed, no switch or circuit changer or commutator to handle, and no danger of failure to operate.

The Transmission Gear.—The transmission gear is typical for many French and American carriages, being very nearly the simplest device of the kind at present on the market. As shown in the accompanying sectional diagram, it consists essentially of two parallel shafts. Of these, the countershaft carries four keyed spurs, the largest of which is constantly in mesh, with the pinion on the clutch shaft, thus insuring a constant drive of the countershaft. As may be seen, however, the clutch shaft terminates with this constantly meshed spur, being bored longitudinally, so as to afford a bearing for one end of a second shaft, arranged continuous with it, but turning separately. The entire length of this second shaft between bearings is of square section, so that a double-faced pinion may be slid from end to end by means of a fork set at one end of the gear-shifting lever.

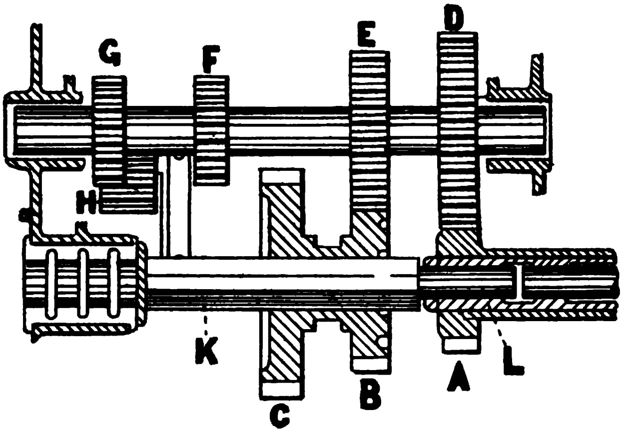


FIG. 277.—Diagram of the Decauville Transmission Gear. A is the spur pinion at the end of the clutch shaft; B and C, spurs on the sliding sleeve; D, E, F, G, spurs keyed to the second motion shaft; H, the reverse pinion, constantly in mesh with G, and giving the reverse, when in mesh with C also; K, the square portion of the drive shaft; L, portion of same journaled into the clutch shaft.

The operation is readily understood: When the gears are in the neutral position shown in the diagram, the clutch-shaft pinion drives the countershaft, without transmitting motion to the road wheels. When the double-faced gear is moved to the left, so that the second small pinion on the countershaft meshes with the larger of the two on the square shaft, the low speed forward is obtained. By sliding the sleeve to the right, so as to bring the larger countershaft gear into mesh with the smaller one on the square shaft, the second speed is attained. By sliding the sleeve all the way to the right, so that, by a form of claw clutch its right-hand gear grips the pinion on the clutch shaft, the highest forward speed is obtained, the drive being then continuous from the motor to the road wheels. The reverse is obtained when the sliding sleeve gears are moved all the way to the left, so that the larger of the two meshes with an idler pinion, constantly driven from the end gear of the countershaft, by which means the rotation of the square section shaft, and of the road wheels is reversed.

FIG. 278.—Decauville Car, with Side Entrance Double Phaeton Body.

Brakes and Control.—Like other standard French cars, the Decauville has two sets of brakes. The first, worked from the upright push pedal to the right of the steering pillar, is a band clutch on a drum just to the rear of the transmission gear case. The second brake, consisting of the usual compression bands on each of the rear wheel hubs, is operated by a hand lever at the right of the driver's seat, outside of the change-speed lever. It normally stands upright, as shown in the cut, and is thrust forward in the act of setting the brakes. Except for the fact that the pedals are upright and are operated by pushing forward, instead of by being depressed, the control system is very similar to that shown in the cut of the Locomobile operating devices.

FIG. 279.—The Winton Two-cylinder Tonneau Car.

The Winton Gasoline Carriage.—The well-known Winton carriage, formerly built with a single-cylinder motor, but now, in some models, with a double opposed cylinder, embodies many excellent features. The front and rear axles are connected by two reach rods arranged to form a triangle, whose apex touches the centre of the forward axle, where a swivel joint is made, giving the required flexibility on uneven roads. The body frame, resting above the springs, is constructed of seasoned oak, joined at the corners by iron angle pieces. The adjustment of the transmission is regulated by two distance rods, one at either side of the carriage, between the body and the running gear.

The driving connections are direct from the sprocket, keyed to a sleeve on the main shaft, to another sprocket on the differential gear drum on the rear axle. The operations of throwing on the power and changing the speed is accomplished by two friction clutches, while the reverse is obtained by a third clutch, as presently shown. The control of this apparatus is by means of two levers rising to the right hand of the driver. The longer of these two, when drawn back, connects the driving gear and motor, and. when shifted all the way forward, applies a powerful brake to the differential drum. The shorter of the two levers operates the speed changing and reverse gear; one pull back throwing in the reduced or hill-climbing gear, and one pull forward engaging the reverse.

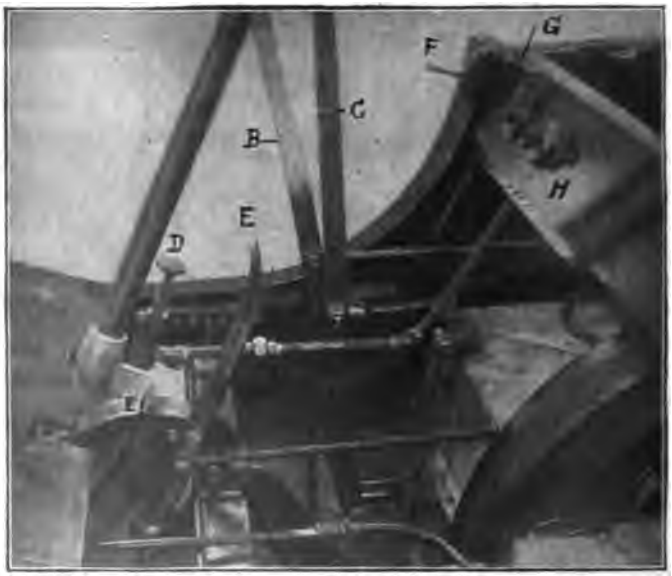


FIG. 280.—Winton Pedals and Levers, foot board removed. B, outside hand lever, pulled to backward extreme clutches high speed into action, idle in mid-position, forward extreme, applies emergency brake to motor shaft brake drum. C, inside hand lever, forward extreme, engages backing gear, rear extreme, engages slow forward speed. D, compressed air release, pedal motor control. E, rear wheel brake treadle, retained by ratchet, EI. F, spark advance, retained by notched quadrant. G. muffler regulation. H, battery switch.

In addition to the brake, already mentioned, there is a special emergency brake, operated by a foot pedal, which is to be used only when the lever fails to operate. The steering in the latest models is controlled by a hand-wheel actuating an irreversible worm gear, somewhat after the design of the Panhard carriages, as shown in Fig. 48.

The Winton Motor and Attachments.—The Winton motor is conspicuous for combining several excellent features of construction and operation. The two cylinders are cast and bored separate, without jackets, thus enabling a thorough hydraulic test for discovering any possible leaks. The cylinders are bolted end to end through flat extensions cast on one side. Both ends of the cylinder castings are formed as square flanges, and between these aluminum plates are screwed to form the water jackets. By this arrangement the exhaust valve stems and chambers are entirely surrounded by the circulating water, being thus perfectly cooled.

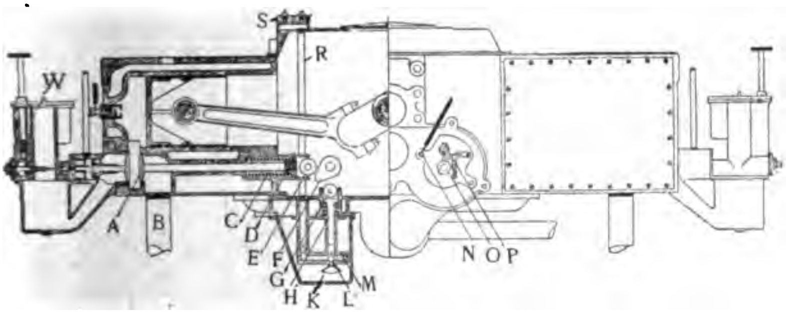


FIG. 281.—Sectional Diagram of the Winton Two-cylinder Motor and Parts. A, exhaust valve; B, pipe leading exhaust gases to muffler; C, exhaust valve spring; D, set screw; E, roller engaging cam, F, which also engages with roller, G, and operates oil pump piston, H; K, filter for oil forced from pump; L, ball valve on oil pump; M, by-pass for excess of oil from pump; N, primary wire from coil to breaker box; O, spark cam; P, contact adjusting screw; R, vertical pipe for oil forced from pump; S, oil conduit and adjusting screws to regulate flow of parts; W, pin projecting from float in carburetter. This cut also shows the shape and position of the carburetters, of the inlet valve air-line relief pipe, and the sparking plug. The hand wheels and spindles rising from the carburetters serve to regulate the maximum output of gasoline at each suction stroke.

As shown in the sectional view of this motor, the exhaust valves and sparking commutator are operated from the two-to-one

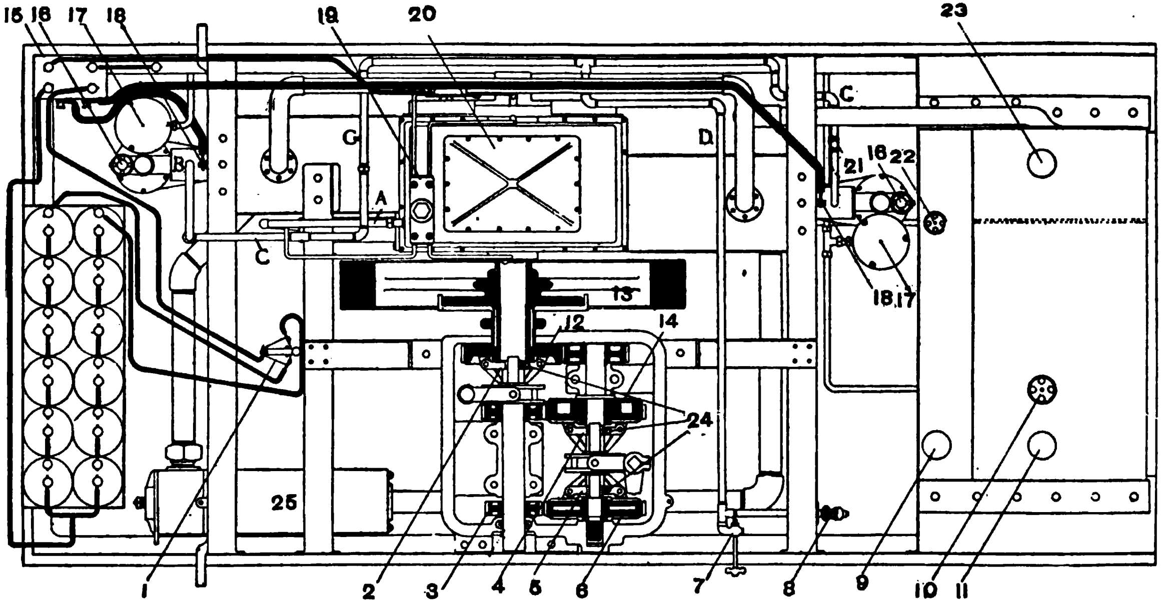


FIG. 282.—Plan View of Engine and Working Parts of the Winton Two-cylinder Car. Switch under driver's seat (1); spur gears in transmission case (2, 3, 4, 5, 6); air-line set governor valve for regulating air pressure in motor (7); foot button for controlling air-line system and throttling motor (8); oil tank cap (9); gasoline tank cap (11); gasoline valve (10); friction gear clutch (12); fly-wheel (13); slow-speed friction gear (14); spark coil (15); gasoline valve on carburetter (16); float pin (17); spark plug (18); oil box into which oil is pumped for distribution to working parts (19); cover of engine case (20); poppet valve on air line to relieve back pressure on air pump (21); valve for filling main oil tank (22); cup for filling water tank (23); adjusting nuts on speed gears (24); muffler (25). The lettered parts are: A, the air pump; B, the inlet valve chamber; C, C, C, the pipes of the air line; D, the pipe leading to the air line control valves, 7 and 8.

shafts, as is also the oil pump, for distributing lubricant to all the bearings. This oil pump consists of a plunger held in normal position by a spring and actuated by the exhaust-lifting cam.

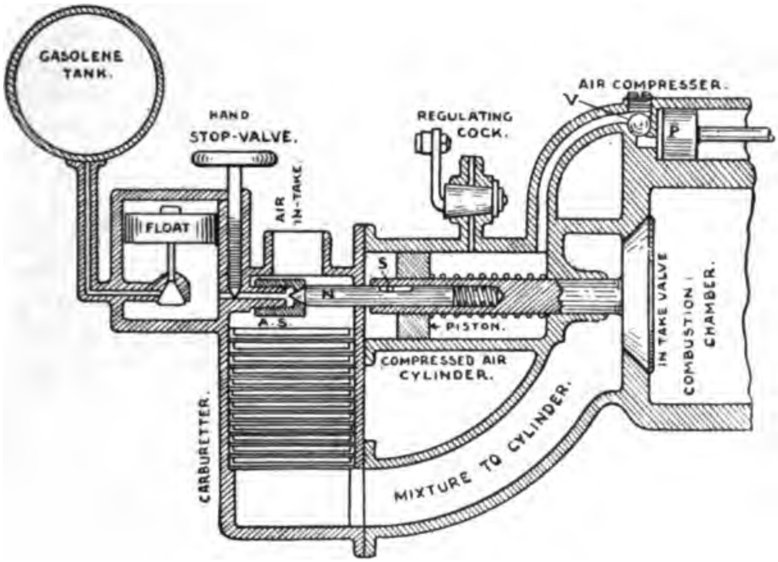


FIG. 283.—Diagrammatic Sketch of Winton's Carburetter and Intake Valve Action. The air compressor piston, P, is driven directly from one of the motor pistons, and forces air past the check valve, V, into the compressed air cylinder, where it operates to hold the piston to the left, and keeps the intaking valve closed, regardless of the piston suction tending to open the valve by moving it to the right. By means of the regulating cock the pressure may be reduced in the air cylinder, thus permitting the intake valve to open, more or less as the air pressure is more or less reduced in the cylinder. The needle valve, N, is seated in and carried by the intake valve stem, is spring pressed to the left by a coiled spring at its right end, is retained by a cross pin, S, and co-acts with the adjustable seat, A, S, to close or open the passage of gasoline from the float chamber to the carburetter underneath, whence the mixture is drawn to the cylinder through the intake valve. No gasoline can go to the carburetter without the motor piston is moved, and more or less gasoline goes to the carburetter as the intake valve is lifted more or less. The regulating cock governs the action of the motor by determining the amount of air that is allowed to escape through the vent. It corresponds to the set governor valve (7) in the previous figure. This cut, reproduced by courtesy of the "Automobile Trade Journal," shows only the theory, not the exact arrangement of the parts.

The oil forced by the plunger passes through a filter and ball valve, upward to the distributing chamber at the top of the cylinder, whence it is distributed, under pressure, to the bearings, through the system of tubing shown in the plan view of the engine and carriage. Any excess of oil is carried off through a by-pass valve, thus preventing flooding of the bearings.

The Winton Control System.—The most conspicuous feature of the Winton carriage is the pneumatic control system, already described in diagram in the preceding chapter. The Winton system throttles the quantity of the mixture, the quality remaining always uniform. The throttle is actuated automatically by air pressure, produced by a small plunger pump at *A*, secured to the rear end of the crank chamber and extending parallel with the rear cylinder. The pump piston is connected to the piston in the forward engine cylinder by a connecting rod, and the air pump. therefore, makes the same number of strokes per minute as either of the engine pistons, and each of its delivery strokes corresponds in time with a suction stroke of the engine. The pump draws warm air from the crank pit and delivers it into a pipe line, *C C C*, leading to the two inlet valves, *B*. From this pipe line another line, *D*, extends to the escape valves, 7 and 8. It is only through these valves that the air can escape. Valve, 7, is the "set governor" for regulating the amount of fuel taken at even running, when the accelerator button, 8, is not depressed, and thus predetermines the maximum effect of the motor. It is operated by means of a dial lever at the side of the seat. Valve, 8, is operated by means of a foot button under the operator's right foot. A spring holds the foot button valve on its seat when there is no foot pressure against it.

On the inlet valve in the carburetter is a small plunger, fitting into the cylinder to the right of spring, *S*, in the section of the carburetter, and between it and the inlet valve is a bushing that acts as a stuffing box. The air pressure leads to this small cylinder, and unless the pressure is relieved by opening either of the valves, 7 or 8, there is no chance for the inlet valve to unset and admit to the engine cylinder a charge of gas. On the extremity of the inlet valve is placed a conical needle valve, the taper of which is so proportioned that a lift of the inlet valve, allowing a certain volume of air to pass into the carburetter, will unseat the needle valve to admit into the carburetter a proper quantity of gasoline which, vaporizing and mixing with the air, produces the correct explosive mixture; consequently, no matter how great or small the charge entering the cylinder, the quality remains uniform.

With the air line entirely closed, the inlet valve cannot lift because of the air pressure against the plunger in the small cylinder. On relieving the air pressure by opening either or both of the escape valves, 7 and 8, the pressure exerted on the plunger is relieved so that the inlet valve may lift correspondingly. The engine then draws a proportionate supply of mixture and reaches a relative speed. By pressing upon the foot button, the operator may relieve the air pressure by minute degrees from the entirely closed point to a point where the pressure in the air line is no greater than that of non-compressed air, so that the Winton motor is governed with extreme flexibility.

The air line may also serve as an automatic governor even if the air relief, 7, is but partially open and that the motor temporarily tends to increase in speed; the air pump, being attached to the piston, increases speed in the same proportion, and the air pressure is higher in the line because the area of the air relief has not been increased though the pump speed has. With the pressure increased on this inlet plunger, the valve will not lift as high, and throttles, thus bringing down the speed of the motor.

Assume the motor tendency to decrease in speed. The pressure in the air line will decrease because the pump is not working as fast as before, and because the relief opening has remained unchanged. As a result, the inlet valve will lift higher, allowing a greater charge to enter the cylinder, which will immediately accelerate the speed.

The Winton Transmission Gear.—The Winton change-speed gear, by the use of three pairs of interlocking spurs and three friction clutches of familiar type, can give two forward speeds and a reverse. The main shaft carries two spur wheels, *A* and *B*, keyed in the positions shown, and a sleeve carrying the sprocket, *C*, and the spur wheel, *D*. The counter-shaft has spur, *L*, keyed to it, and spurs, *K*, and *N*, turning loosely until clutch, *H* or *M*, is thrown in. The main shaft and the sleeve are caused to rotate together through the contact surfaces of the friction clutch, *E*. To obtain the slow speed forward, the clutch, *F*, is thrown on by shifting the thimble, *G*, thus bringing the sleeve, carrying the sprocket, *C*, and the gear, *D*, into operative relations with the main shaft through the friction clutch, *E*. The second speed forward may be obtained by throwing in clutch, *H*, by sliding the thimble, *J*, and power is then transmitted from the gear, *A*, which is fast on the main shaft, through *K* and *L* on the countershaft to spur, *D*, which is screwed to the sleeve on the main shaft, in rigid relation with the sprocket, *C*. Similarly, the reverse movement is obtained by throwing on the clutch, *M*, by sliding the thimble, *J*, in the opposite direction, with the result that the motion is transmitted from the main shaft to gear, *B*, to

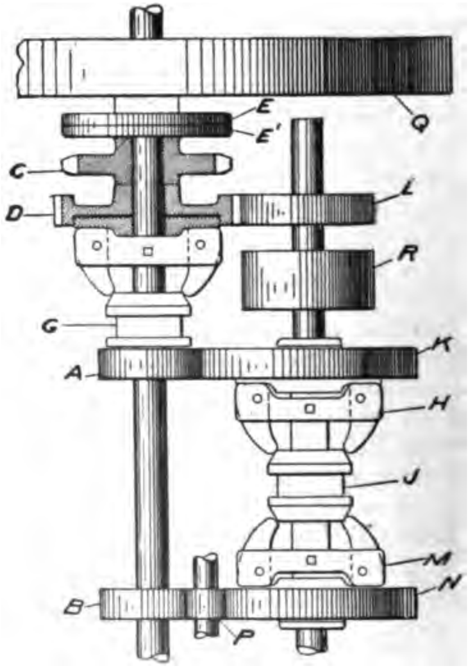


Fig. 284.—The Winton Change Speed and Reversing Gear. A and B are spur gears keyed to the crank shaft of the motor. C is a sprocket, and D a gear, of one piece with it, which turn loose on the main shaft. E and E′ are friction discs, which connect C and D to the main shaft when the clutch, G, is thrown in. K and N are spur gears loose on the countershaft, and meshing with A and B, as shown. When clutch, G, is thrown in, the first speed forward is obtained; when clutch, H, is thrown in, the second speed forward; and when clutch, M, is thrown in, the reverse. The clutches, H and M, are operated by a lever actuating spool, J. P is an idler pinion reversing the motion transmitted from B to N. Q is the fly-wheel of the engine; L, a gear transmitting motion from the countershaft to the sprocket; and R, the brake drum.

gear, *N*, through the intermediate idler gear, *P*, to the countershaft, and thus, through *L* and *D*, to sprocket *C*.

The operation of this gear involves the use of two levers—one for throwing clutch, *G*, and operating the band brake on drum, *R*, the other for throwing clutches, *H* and *M*.

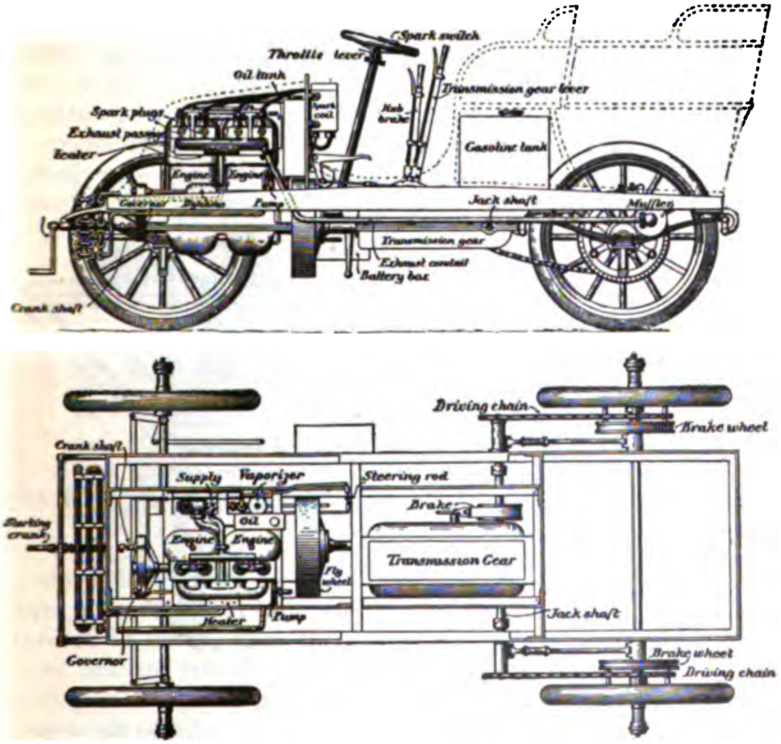
The Winton Racer.—The name of Winton is associated with several of the fastest racing cars that have been built in the United States, notable among which is the Winton "Bullet," shown in an accompanying illustration. This carriage has an eight-cylinder motor placed transversely in the frame, and consisting of two units of four cylinders each, connected by means of a universal flexible joint. In size and mehanism each cylinder is a duplicate of the Winton Touring Car motor construction. One carburetter supplies the mixture for each unit of cylinders, and only one coil is used for igniting; the current passing to the new Winton type of distributor, from which it is commutated to each separate cylinder. A positively operated, internally-expanding clutch transmits the power to the longitudinal telescopic universal drive

FIG. 285.—The Winton Racing Car, "Bullet, No. 2."

shaft through bevel gear connection to the differential case. The rear axle is equipped with adjustable ball bearings throughout. There is no change speed gear in the system; the high power developed by the motor in combination with the Winton system of air governing, and the peculiar pattern of clutch makes it possible to pick up speed gradually, and without jerking, on the direct drive. The brake control consists of band brake on the fly wheel and two sets of rear hub brakes, the outside hub brakes being friction bands, and the inside brakes of the expansion type. The clutch lever by the forward movement sets the brakes similar to the high speed lever on the Winton Touring Car. A separate foot lever controls the fly-wheel brake. The frame construction is of armored wood with body hangers of sheet steel. Both front and rear springs are semi-elliptical. The steering gear shaft extends through the body-side to which a drop lever connects to the upper end of the right wheel steering knuckle through a horizontal link parallel to the frame. The cooling system consists of two tanks integral with the cylinder jackets; two separate circulating pumps, and a single radiator placed at the forward end of the car. The oiling is by the standard Winton system of positive feed lubrication. The gasoline tank is placed at the rear of the seat and has a capacity for 200 miles continuous running. The wheel base of this machine is 9 feet 6 inches, with a standard tread of 56½ inches. The wheels are equipped with 34x4½ tires.

The Winton Bullet No. 2 has been used by only one professional racing man, Barney Oldfield, in whose hands it has proved the most successful racing automobile on either side of the Atlantic. It has won 26 races, 6 second and 3 third prizes in 36 starts, and holds all the world's track records from one mile in 54 4-5 seconds to fifteen miles in 14:21. It has never been driven in a track race or record trial beyond fifteen miles. With this machine Barney Oldfield won the straight-away world's championship on the sand beach at Daytona, Fla., in January, 1904, defeating Wm. K. Vanderbilt, Jr., in his Mercedes car, which is the highest-powered and fastest automobile ever imported to this country.

The Riker-Locomobile Car.—A prominent American car, built on French lines, is that known as the Locomobile. It combines many features of exceptional excellence, as regards both construction and operation. Two sizes are manufactured—a nine-horse-power, with a two-cylinder motor, and a sixteen-horse-power with four cylinders, both being susceptible, according to claims of a twenty-five-per-cent. output above rating at 1,500 revolutions or over. The two-cylinder motor, being arranged for higher speeding, is capable of a greater power output.



FIGS. 286, 287.—Side Elevation and Plan of the Riker-Locomobile Chassis.

The Chassis and Running Gear.—The frame of the vehicle is of channel steel bars of rectangular shape, and suitably braced at points intended to carry the greatest weights. It is, moreover, tapered at either end by shaving off the upper arm of the C-shaped section, so as to reduce the height from 4 inches at the centre to 2½ inches at the extremities. Upon this framework the body, engine and all working parts are mounted, and it is supported on the two axles by four semi-elliptical springs. The wheel base of the 15-horse-power car is 84 inches. The wooden wheels, of artillery pattern, measure each 34 inches diameter, and are equipped with 3½-inch detachable tires. The rear axle is a solid forging, upon which the wheels turn freely, being driven from the countershaft. The axle spindles are tapered to fit the wheel boxes, and are provided with spiral grooves to conduct the oil to the bearing surfaces, which are plain, all ball and roller bearings being omitted in these cars.

The motor has already been described in the foregoing chapter, leaving nothing to be added here. The water circulation is of the type generally used on heavy gasoline cars—the jacket water being forced by the pump through a radiating coil, 6 inches in height by 3 inches in width, and composed of 18 parallel tubes. In case of derangement of the pump, however, the water tank is placed at such a height above the coil as to permit of natural gravity circulation by the differing temperatures of the inlet and outlet. The capacity of the tank is 15 gallons.

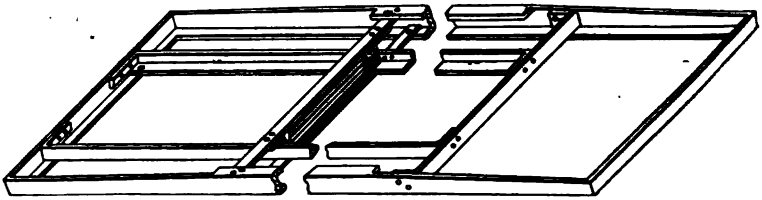


FIG. 288.—Sketch of the Riker Underframe, showing the way in which the channel steel bars are tapered toward either end of the chassis.

The engine is set over the forward axle, sidewise to the direction of travel, and turns the main shaft running in the length of the frame, as in the standard French cars. The drive is through bevel gears to the transverse jack shaft, whence the power is transmitted by chains and sprockets to the rear wheels, turning loose on the dead rear axle. The usual brakes are included, one on the differential case sleeve on the transverse jack shaft, operated by a foot pedal, the other on drums on the rear wheel hubs, operated by a lever to the right of the driver's seat.

The Locomobile Transmission.—The transmission gear of the Locomobile gasoline carriages is of the gear type, and is arranged to give three forward speeds and one reverse, the high speed being direct from the main shaft. The efficiency of this apparatus is further augmented by the fact that the gear-shifting lever is automatically locked at every movement until the main clutch is thrown off, thus effectualy escaping needless friction and injury to the gears. The cone clutch, which is normally held against the face of the flywheel by coiled compression springs, is bolted to a flanged sleeve carried on the squared end of a short shaft, 1, terminating in the spur pinion, *A*. This pinion, as shown in the figure, is always in mesh with the spur gear, *B*, on a parallel secondary shaft, 2, and continues to turn the secondary shaft so long as the engine is in motion. The spindle on which *A* turns has a longitudinal bore serving as a bearing for the shaft, 3, terminating in the bevel pinion, *C*, in mesh with the bevel gear, *D*, on the differential drum of the "jack shaft," 4. The shaft, 3, is square through its entire length between bearings, and carries the sliding pinions, *E* and *F*. Since its rotation is independent of the

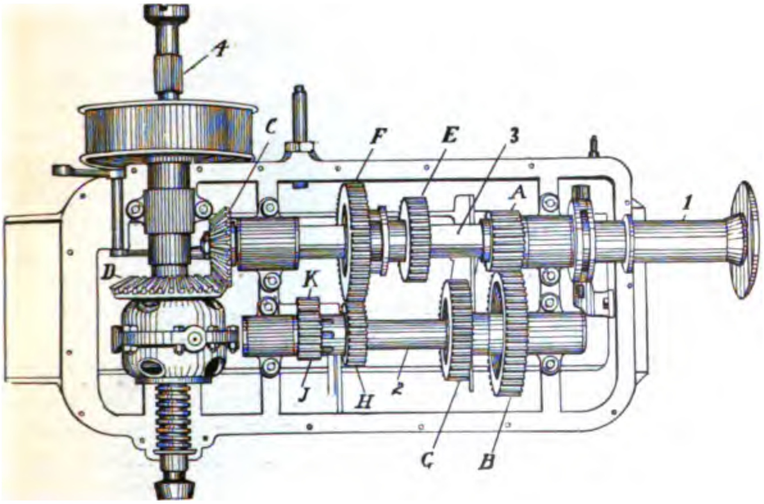


Fig. 289.—The Riker Transmission Gear.

clutch sleeve, 1, it follows that all movements except the high speed forward, must be transmitted from the secondary shaft, 2, through the pinions, *E* and *F*, and since these may be slid into a neutral position, the shaft, 2, may rotate without driving the carriage. The slow speed forward is obtained when gears, *E* and *G*, are in mesh, the second faster speed, when *F* and *H* engage, and the reverse, when *F* engages idler, *K*, which is driven from the secondary shaft through pinion, *J*. For the high speed forward, *E* is slid to the right until internal teeth in its face engage the external teeth on *A*, thus locking the two and making the movement of shaft, 3, continuous with that of sleeve, 1, and driving the carriage direct from the flywheel shaft.

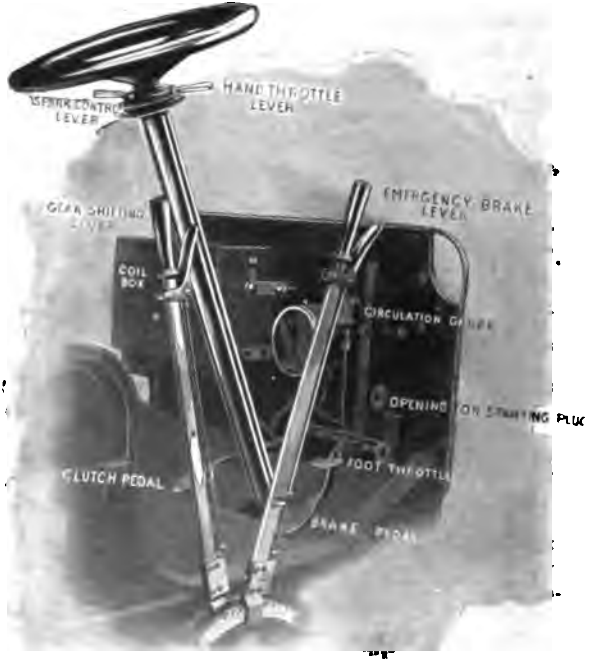


FIG. 290.—Control Levers and Appliances of the Riker Car.

The Locomobile Control Levers.—A carriage using such a change-speed gear as that of the Locomobile 2 and 4-cylinder cars can be readily controlled by the use of a single lever. As shown in the accompanying diagram, the inner of the two levers sliding in notched quadrants may be moved forward through the three forward speeds, and pulled back for the reverse, the clutch being, meantime, thrown out. On account of the high power and ready control of the engine, it is possible to operate the carriage on the high gear most of the time, thus requiring that the lever be manipulated only when hill-climbing or other special necessities demand. The outer lever represents the emergency hub brake, as in other makes of carriage, while the main brake on the differential drum is operated by a speed pedal to the right of the steering pillar. Similarly, the clutch may be thrown by depressing the lever to the left of the pillar. The spark and hand throttle handles are set at the end of rods beside the steering pillar, within easy reach of the right and left hand, respectively. But an auxiliary throttle pedal or accelerator is operated by a pedal beside the brake; thus enabling the carriage to be perfectly operated without removing either hand from the steering wheel. The throttle connections having already been shown, it will not be necessary to describe them here.

The Packard Car.—The Packard four-cylinder touring car is one of the best examples of American machine constructed on French lines Its motor cylinders are cast in pairs integral with their valve chambers and water jackets. Both inlets and exhausts are mechanically operated from one cam shaft, being set on the same side of the cylinders.

The framework is of angle-steel, slightly tapered toward either end, and supported on the springs above the axles. According to the usual plan, the motor is placed forward under a Mercedes type square front bonnet, and is connected by a clutch to the transmission gear. The latter apparatus, by an excellent variation on current models, is hung just forward of the rear axle, and drives direct to the differential drum by bevel gears. This arrangement saves the extra complication of a transverse jack shaft, with chain and sprocket connections to loose-turning drive wheels. The live rear axle is enclosed in a strongly enforced sleeve casing, while a longitudinal adjustable strut, or distance-rod, connects it by fixed distance at the centre of the body frame to the left of and below the universal joint of the driving shaft.

The Clutch and Brakes.—The clutch is of the expanding band brake type, and is arranged to be thrown out by pressing forward on a pedal to the left of the steering wheel. As in other high-powered cars, there are two sets of brakes, the first set by a foot pedal to the right of the steering wheel, the second—the emergency brake—by a hand lever rising to the right of the driver's seat, according to the familiar arrangement. A notable variation from the usual design is found in the fact that neither of them acts upon the differential drum, or on any part of the drive shaft. The pedal brake is an expanding band within each of the rear axle drums, while the lever brake is a constricting band acting upon the outer circumference of each of these drums. The internal brake consists of a cast iron ring split at the top, with an egg-shaped cam so arranged between the two ends that the whole ring may be expanded and made to bear against the inner surface of the drum. As may be understood from an examination of the sectional elevation of the Chassis, the cam will expand the ring, if the lever be carried to an extreme position, either backward or forward. This involves that the connections be carefully adjusted, in order to have the lever rest in the neutral position. The external band brakes are of the ordinary pat-

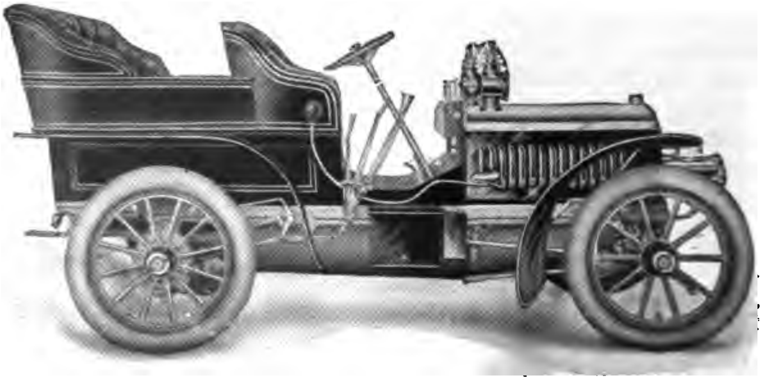


FIG. 291.—Packard Voiture Legere Tonneau Touring Car.

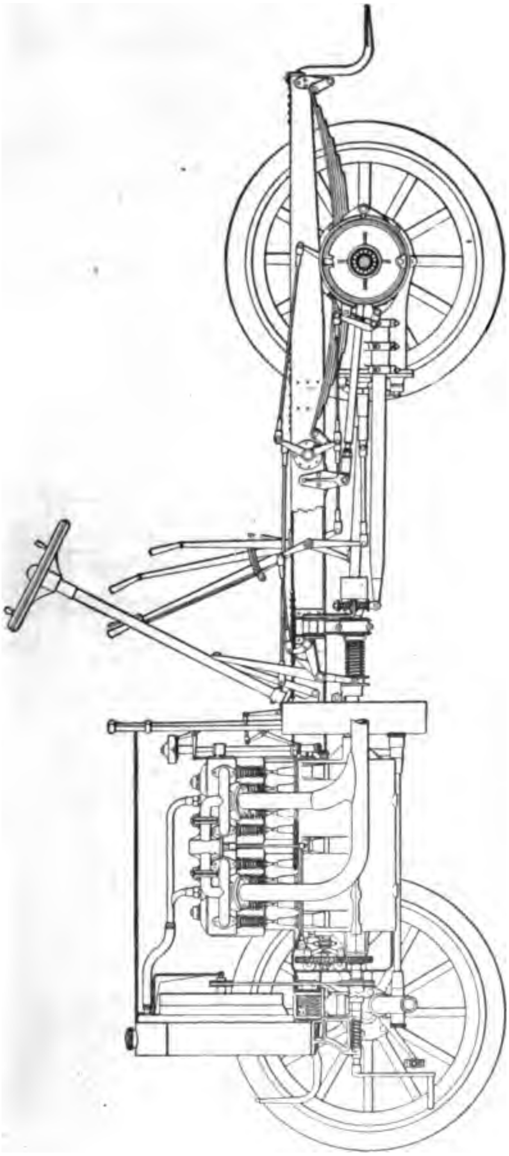


FIG. 291a.—Sectional Elevation of the Packard Chassis.

tern, and are actuated by a backward pull on the lever. If both brakes be set at the same time the resistance is sufficient to stop the car within a very small distance.

The Transmission.—The transmission gear, hung just forward of the rear axle, is of the sliding gear type, giving three forward speeds and one reverse As shown in the accompanying sectional diagram, it consists of three shafts: (1) the drive shaft connected by a universal joint to the clutch, and square through the greater part of its length to allow of sliding a sleeve holding two spur gears; (2) the bevel pinion shaft, carrying a single spur gear at its inner end and bored to serve as a bearing for the drive shaft; (3) the second motion shaft, to which are keyed three spur gears, two of them of diameters suitable to mesh consecutively with the sliding gears on the drive shaft, giving the lowest and intermediate speeds, and the third constantly in mesh with the single gear on the bevel shaft. The top speed, as in the Decauville, Peerless, Riker and other modern transmissions, is obtained by sliding the two-gear sleeve all the way back (to the right in the diagram), so that its teeth mesh with internal teeth cut in the circumference of the bevel shaft gear, thus making the drive direct from the motor. The reverse

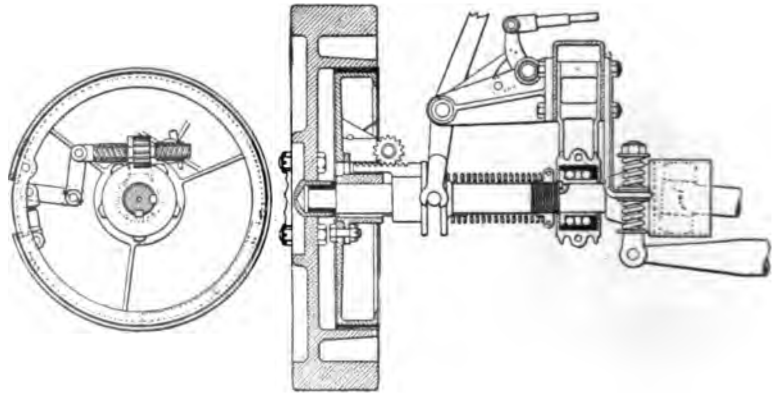


FIG. 292.—End View and Cross Section of the Packard Expanding Band Clutch.

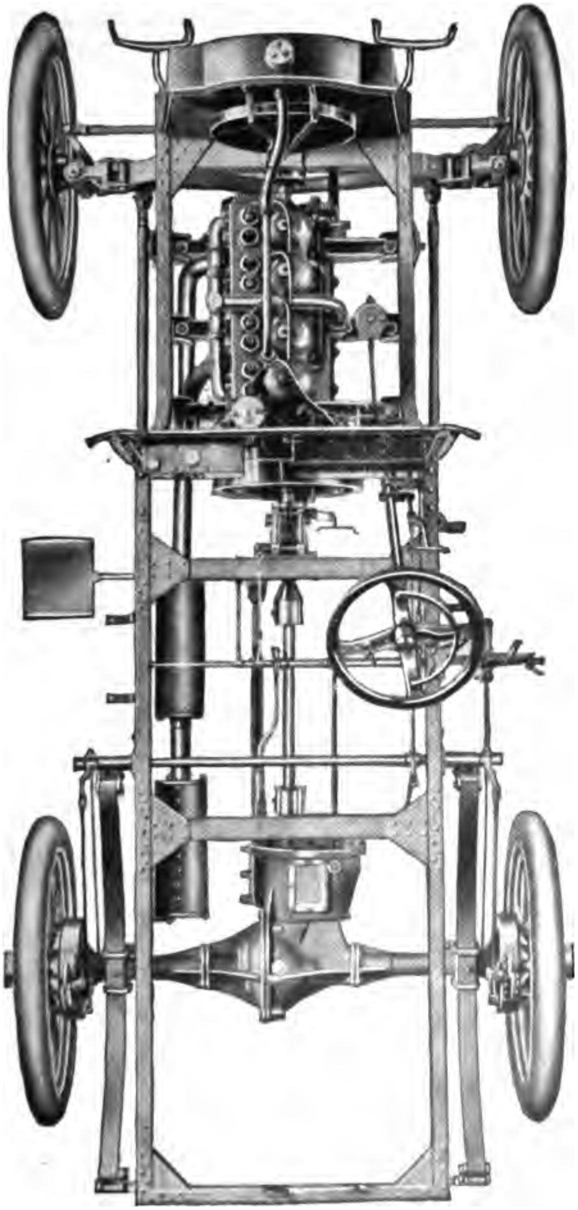


FIG. 293.—Plan View of Packard Voiture Legere Chassis, showing working parts and control apparatus.

is obtained when the gears on the sliding sleeve are in the neutral position (indicated by the dotted outlines in the cut), by operating the short reverse lever, thus causing an idler pinion, hung on a bell crank, to be thrown into mesh with the forward (left) end gears of the drive and top shafts.

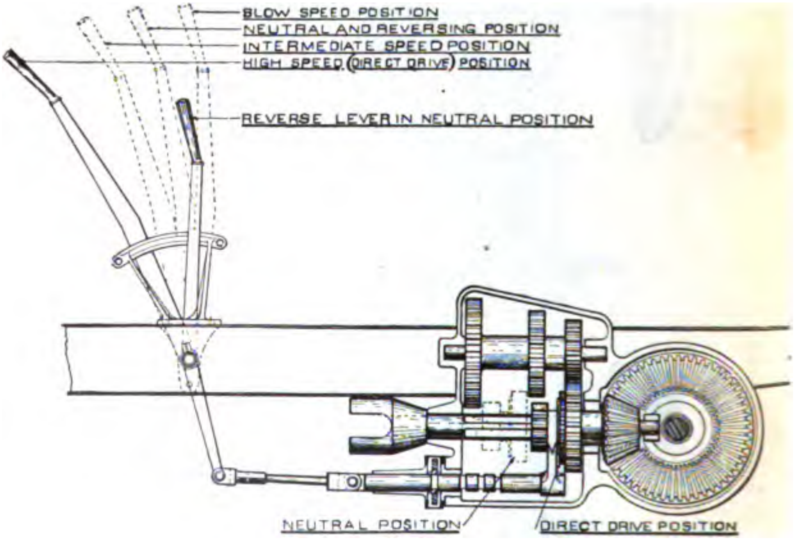
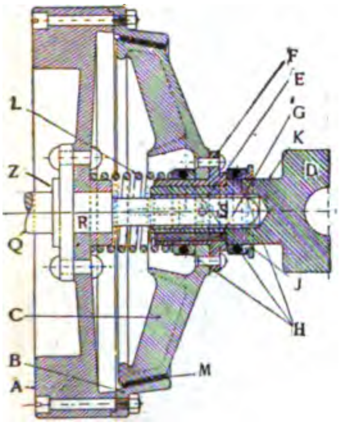


FIG. 294.—Diagram of Control Levers and Transmission of the Packard Car.

The Peerless Car.—The Peerless four-cylinder car combines several excellent features borrowed from both French and American masters. The framework is of cold-rolled pressed angle-steel, fully reinforced by trussing. The engine has the four cylinders cast separately, integral with their jackets and valve chambers, the valves being mechanically operated from cam shafts on either side of the cylinders. The friction clutch, set on the end of the main shaft of the engine, differs from the usual type in the fact that the male cone is contained within the female cone, the friction surfaces being normally held together by a powerful spring pressing outward and backward, instead of inward and forward, as in older types.

As shown in the accompanying sectional diagram, the fly-wheel, *A*, is a driving fit to *R*, and is bolted to the flange, *Z*. The conical clutch rim, *B*, being bolted upon the fly-wheel. The universal coupling, *D*, connects with the transmission gear, has a bushing, *E*, and runs freely on the motor shaft, *S*. The collar, *F*, is keyed to the universal coupling, *D*, by key, *G*, and the cone, *C*, is riveted to *F*, thus making *C, D* and *F* practically one. At *M* is a band of leather riveted to the rim of *C*, thus completing the clutch. The surface, *M*, is always held firmly against the inwardly inclined rim of *B* by the strong spiral spring, *L*. At the points indicated by *H* are the ball bearings, designed to take up the thrust, when disengaging the clutch, by pressure along the shaft from point, *K*, where a yoke is fitted and slid by a series of levers from pedals before the driver's foot. At *J* is a flange on the ball retainer, *H*, turning freely on shaft, *D*.



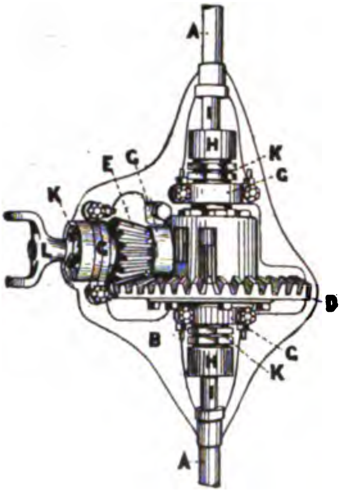


Fig. 295.—Internal Cone Clutch of the Peerless Car. A, engine fly-wheel; B, female cone; C, male cone; D, universal coupling on male cone; E, bushing on D; F, collar keyed on D; G, key; H, ball bearings for taking up the thrust on disengaging clutch; J, flange on ball cone; K, receptacle on D for operating yoke; L, spiral spring for retaining clutch surface contact; M, leather band riveted on C, giving good friction surface; Q, main shaft; R, portion of shaft turned down to fit fly-wheel; S, portion of shaft turned down to receive clutch sleeve; Z, flange to which fly-wheel is bolted.

Fig. 296.—Bevel Driving Apparatus on Rear Axle. A and B, sleeve and case for axles and gears; D, the driven gear; E, driving pinion; G, ball bearings on E; H, H, universal couplings on the differential; K, K, K, adjustments; L, yoke for flexible driving shaft.

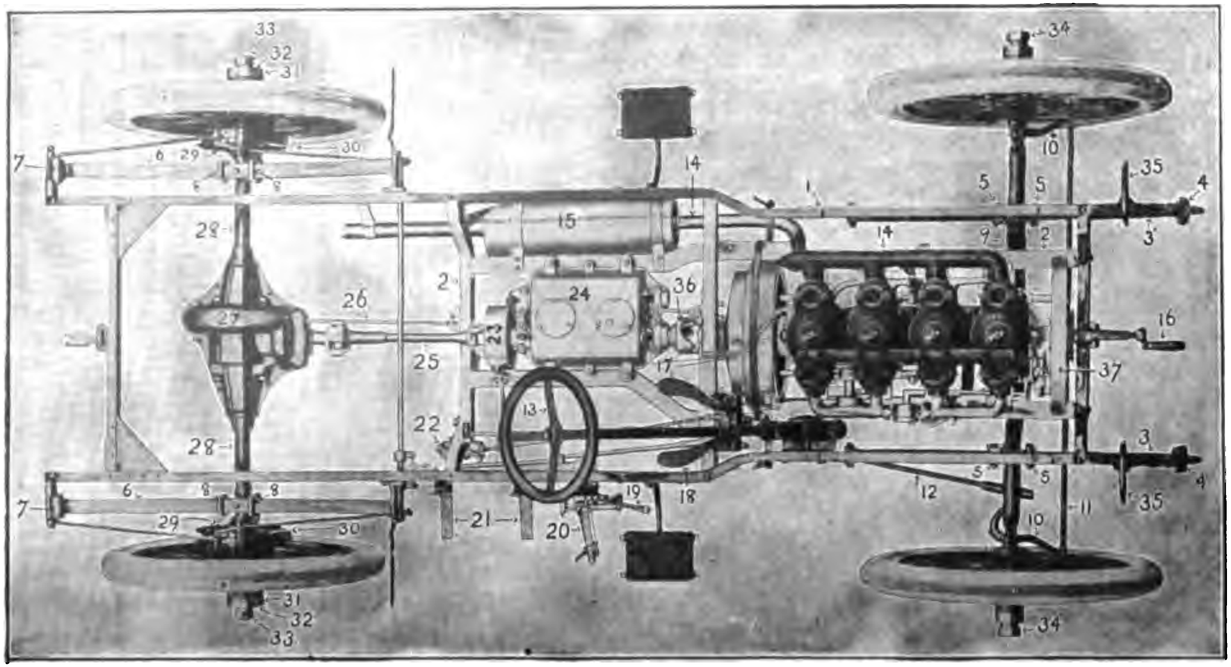


Fig. 297.—Chassis of the Peerless Four-cylinder Car, showing parts numbered: steel frame (1); motor and transmission frame (2); front springs (3); spring toggles (4); spring clips (5); rear springs (6); spring toggles (7); spring clips (8); front axle tubes (9); steering knuckles (10); steering link (11); steering rod (12); steering wheel (13); exhaust pipe (14); muffler (15); starting crank (16); clutch pedal (17); brake pedal (18)); gear shifting lever (19); brake lever (20); battery box hangers (21); interlocking device for gear shift, brake and clutch (22); foot brake band (23); transmission gear case (24); driving shaft (25); distance-rod (26); differential case (27); rear axle tubes (28); brake drums (29); brake bands (30); hub clutch bands (31); hub clutch plates (32); hub caps (33); front hub caps (34); lamp brackets (35); coupling on clutch shaft (36); cover for second-motion gears on motor (37).

The Peerless Transmission.—The transmission used on the Peerless carriage closely resembles that of the Decauville, varying from it principally in the manner of engaging the reverse. As in the Decauville transmission, the driving shaft ends in a single spur gear constantly in mesh with the large end gear on the parallel second shaft, and bored longitudinally to serve as the bearing for the slide-gear shaft squared through its entire length between bearings and carrying two gears on a sliding sleeve. As in other similar transmissions, the top speed is obtained when the sleeve is slid all the way forward (to the right in the diagram), so that internal teeth, cut on its inside circumference, engage the external teeth on the clutch-shaft gear. Since this latter gear is always in mesh with the end gear of the second shaft, the second and third speeds are obtained by meshing between the second shaft gears and those on the sliding sleeve. The reverse is obtained when the sleeve is slid all the way back (to the left), so that the rear gear meshes with an idler shown beneath the second motion shaft. Since this idler spur is hung on a bell-crank device having a fork to engage a pin on the sliding sleeve between the gears, it is slid forward, as the sleeve is slid back, so as to engage the rear spur on the second motion

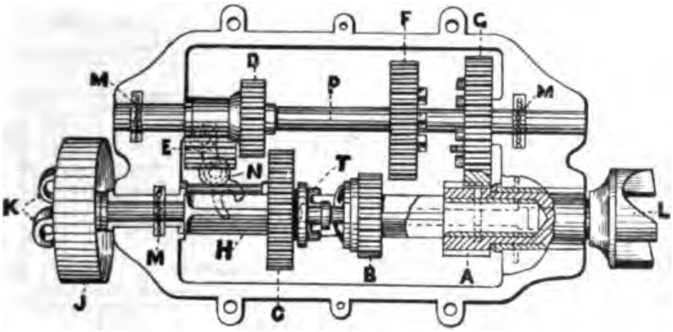


Fig. 298.—Diagram of the Peerless Transmission. A, pinion on shaft coupled to clutch at L, B, C, pinions on sleeve sliding on square section of shaft, H, journaled into A, as shown in sectional view; D, pinion on countershaft, P, giving low speed in mesh with C; E, reverse pinion on yoke pivoted at N; F, pinion giving second speed in mesh with B; G, pinion always in mesh with A; H, square section of drive shaft; J, brake drum; K yoke for coupling on flexible drive shaft; L, flexible joint coupling; M, M, M, chain bearing oilers; N, pivot and lever of yoke carrying E, that is moved forward (to the right) when a pin at I engages fork, thus bringing C and D into mesh with E for reverse. High speed forward is obtained when internal teeth in P fit over external teeth on A, giving direct drive from the motor from L to K.

shaft, thus bringing the two shafts into gear and causing the motion to be transmitted in reverse direction. The drive is by bevels direct to the differential drum on the rear axle, the transmission gear being hung midway on the frame. As in standard makes of car, there are two brakes, both of the clamping or constricting band type; the first on a drum to the rear of the transmission case, operated by a foot lever; the second on drums on the rear axles, operated by a lever at the driver's right hand.

The Haynes-Apperson Cars.—The name of Haynes-Apperson is well known as among the earliest of American automobile builders. Indeed, with the exception of the Duryea brothers, they rank as the pioneers of the industry in this country. Their cars have always been propelled by the double-opposed cylinder engine, already described. In the earlier models, the engine was always set back in the body frame, throwing the bulk of the weight over the rear axle, and thus attaining, according to claims, a superior balance. In the recently perfected tonneau car the motor is set forward under a hood, as in the approved French models; and produces quite as good results.

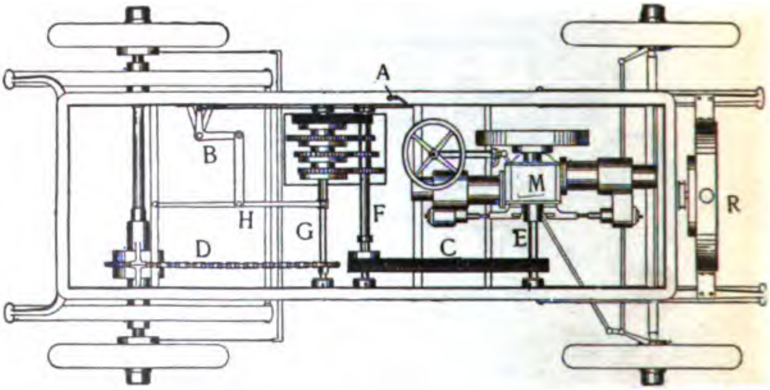


FIG. 299.—Plan Sketch of Chassis of the Haynes-Apperson Tonneau Car. A speed-shifting lever; B, bell crank for shifting speeds; C, silent chain between the main shaft and the speed shaft; D, driving chain between sprockets on clutch shaft and rear axle; E, main shaft of motor; F, speed gear shaft; G, speed clutch shaft; H, swinging rod for changing speeds, moved by B; M, motor; R, cellular radiator.

The frame is of angle-steel, rounded at the four corners and trussed by cross braces that also serve as supports for the engine and other parts. All shafts turn in roller bearings, which give superior endurance, and are arranged to take all end thrusts without the use of balls.

The Carburetter and Throttle.—The fuel gas is supplied to the two cylinders of the engine by two separate carburetters, which are of special design long used on cars of this make, and permit of such exact adjustment as to allow the speed to be varied between 135 and 1,600 revolutions per minute. Each carburetter consists essentially of a mushroom valve, arranged to open against a tension spring under suction of the engine piston, allowing gasoline to enter the combustion space through a needle valve, and air through a variable inlet chamber. The spindle of the needle valve is threaded, so that its lift may be regulated by rotary movement, screwing or unscrewing in its socket. The air inlet chamber may be varied in size and inlet capacity by a cylindrical cover held in place against the tension of a coiled spring around a sleeve slid over the needle valve housing. This sleeve

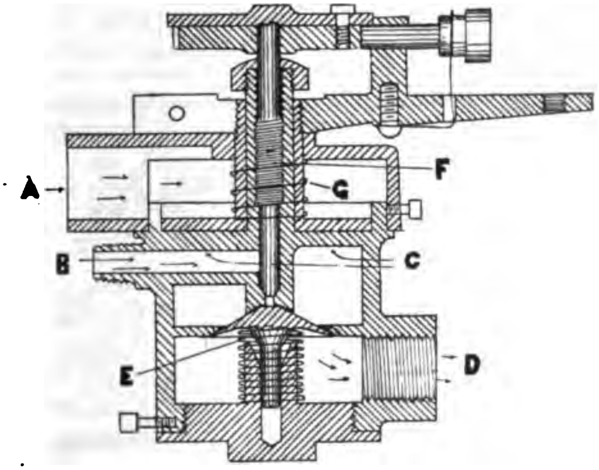


Fig. 300.—Sectional Diagram of the Haynes-Apperson Throttling Mixer. A, air inlet; B, gasoline inlet; C, C, location of air ports into mixing chamber; D, vapor exit to engine; E, mushroom valve held on seat by spring, opened by suction of engine piston; F, threaded needle valve spindle; G, spring for raising upper member of air chamber when released by screw motion of the levers attached to cover retaining screw and needle valve spindle, both being raised or lowered by the same movement.

is also threaded above the top of the air chamber cover, so that a lever worked in a rotary direction by the throttling link may

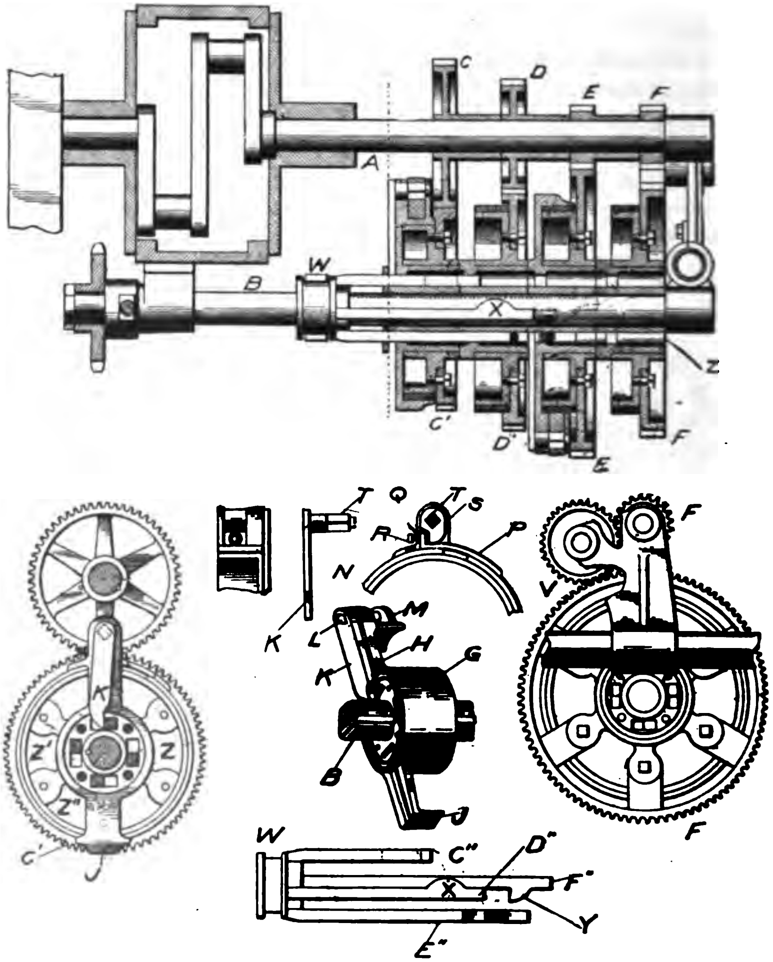


FIG. 301.—The Haynes-Apperson Transmission Gear, shown hung on the crankshaft, as in the lighter cars. The reverse is now accomplished by a chain between F and F', dispensing with the idler, V.

allow the cover to rise or cause it to lower, as the necessity occurs for increasing or reducing the supply of air for the mixture.

Since the same lever handle controls the lift of the needle valve and of the air chamber cover, the proportions of air and gasoline vapor may be maintained within moderately fixed limits. The opening of the needle valve may be varied from a few thousandths of an inch upward, within limits, and only a very slight movement of the stem suffices to increase the gas supply or shut it off entirely. The throttle is operated by a foot button coming through the floor before the driver's seat, and a little practice enables very exact regulation of the speed. There are two sets of brakes, as on other standard carriages, the first on the differential drum, operated by a foot lever on the floor; the other on the rear wheel hubs, operated by a lever at the left of the driver's seat.

The Haynes-Apperson Transmission Gear.—The Haynes-Apperson transmission consists of two parallel shafts, *A* and *B*, the former being driven direct from the crank, or by belt and pulley from the main shaft, as in the later models of this carriage, and carrying four gears, *C*, *D*, *E* and *F*, keyed in its length. The countershaft, *B*, also carries four loose gears, *C′*, *D′*, *E′* and *F′*, each of which is bolted to a band clutch drum, as shown in the illustration. Each of these brake drums, with its attached gear, turns loose on a separate drum, *G*, which is keyed to the countershaft, all of the attached gears, however, being able to turn through the motion imparted from their mates on the main shaft, without transmitting power to the driving mechanism. As may be readily understood, in order to transmit power through any one of the gears on the countershaft, it is necessary to make it rigid with its drum, *G*. The driving sprocket is keyed to the end of shaft, *B*, as shown.

As will be seen in the separate cut, each one of the drums, *G* carries two arms, *H* and *J*, fixed diametrically opposite one another. On the arm, *H*, is carried a lever arm, *K*, pivoted at *L*, and having a short angle of movement by the attachment of its pivot to the bearings, shown at *M* and *N*. On the two extremities of the arms, *R* and *J*, are carried brackets, which hold the leather brake band against the circumference of the drum turning loose on *G*. One end of this brake band is riveted to the brake on *H*, the other to a forged strap, *P*, having at its extremity the lug, *Q*, through which works the adjusting screw, *R*, whose point bears against the dog, *S*. This dog, *S*, is carried on the square section, *T*, of the shaft attached to the lever arm, *K*, already mentioned; so that a slight movement of the lever, *K*, to the left, is imparted to the dog, *S*, whose point bears against the screw, *R*, on the lug, *Q*; thus drawing the strap, *P*, tight around the drum, which is thereby made rigid with the sleeve, *G*, keyed to the shaft, *B*. By this means the gear attached to that particular drum imparts the motion transmitted to it from its mate on the shaft, *A*, to the countershaft, *B*, such motion varying in speed according to the ratios between the meshed gears. The act of giving the required axial movement to the lever arm, *K*, is performed as follows:

The sleeve, *W*, sliding on the countershaft, *B*, carries four fingers, *C″*, *D″*, *E″*, *F″*, of differing length, as shown in the figures. In the extremity of each of these fingers is a lug, such as is shown at *X* and *Y*, the object of which is to engage the point of the lever, *K*, on some one of the four arms, *H*, thus causing it to move its dog, *S*, and tighten the brake band, as already explained. In order to accomplish this act without interference, the positions of the levers, *K*, and of the dogs, *S*, differ in each brake drum. On drum, *C′*, for example, it is at the top of the shaft; in *E′* it is at the bottom; while in *D′* and *F′* it is on the right angle in either direction. For this reason, as may be understood from the cut, the four fingers carried on the sleeve, *W*, are similarly disposed, in order that their lugs, *X* or *Y*, may engage the point of the particular lever, *K*, which it is intended to actuate, without interference. In order that the fingers, *K*, may slide through the drums, *G*, keyed to the shaft, *B*, four suitable channels penetrate the entire series of drums, *G*, as shown at *Z* in one of the cuts.

The sliding sleeve, *W*, is shifted by a lever working on the thimble on its outer extremity, and by causing its fingers to penetrate the channels, *Z*, more or less, can give three speeds forward and a reverse. The reverse is accomplished when the lug on the finger, *F″*, engages the lever, *K*, on the sleeve, *G*, belonging to drum and gear, *F′*, which act enables the motion of pinion, *F*, on shaft, *A*, to be transmitted through the idler, *V*, to *F′*, which will of course, rotate in an opposite direction to *F*, thus reversing the motion of the shaft, *B*. In more recent models of this gear, *F* and *F′* are sprockets and are connected by a chain belt, which accomplishes the end of reversing the travel of the carriage to better advantage than by the use of the idler, *V*. The lever operating the speed-changing works through a bell crank to spool, *W*.

The Pope-Toledo Car.—The Pope-Toledo car is driven by the four cylinders already described in the preceding chapter. The cylinders are cast separate, the heads and valve chambers being bolted on, as shown in the diagram. The inlet valves are operated solely by suction, as in the older types of motor, the mechanical operation having been abandoned by the manufacturers, in spite of the fact that they were among pioneer users in America. The clutch is of the internal-cone type, and is susceptible of easy operation and ready adjustment. As shown in the accompanying diagram, the fly-wheel, *A*, is bolted to a flange on the main shaft, *P*, and carries on its rim the clutch ring, *B*, which forms the female portion of the clutch mechanism. The clutch sleeve, *H* connects at one end to the transmission through a universal joint being bolted at the other end to the clutch cone, *D*. The leather band, *E*, is riveted to the rim of *D*, thus completing the clutch. Four strong spiral springs, *J*, hold the cone, *D*, firmly against *B*. Each may be adjusted by the clutch spring nuts, *K*. The fork for operating the clutch fits into the groove at *H*. It is geared to a pedal at the left of the steering wheel, but is so connected that it is automatically drawn when either of the brakes is applied.

The Toledo Transmission.—The transmission gear used on this car is of a somewhat different type from those previously described. As shown in the accompanying diagram, shaft, *A*, driven by the motor, communicates the power to the sliding gear sleeve, *U*, through the two bevel gears, *C*. Sleeve, *U*, carries sliding gears, *D* and *D'*, and the male portion, *O*, of a miter gear clutch. These parts are free to move endwise, but are prevented from turning independently by long feathers set in opposite sides of the sleeve. The sleeve, *U*, is free to turn on the transverse transmission shaft, *B*. Directly below this shaft is a countershaft, which carries gears, *F*, *F'* and *P*.

The driving gear, *E*, is not fixed to the differential case, but may be held in driving relation thereto by the spring, *Q*, which normally presses the spur-driving gear, *E*, against hub, *H*, and causes teeth on the right-hand face of its hub to mesh with similar teeth on *H*, which is integral with the differential gear case. When teeth on *E* mesh with those on *H*, *E* is locked to the differential case. This relation exists only when the car is being driven on the slow or intermediate speed or the reverse. It will be seen that when driving on the slow speed, sliding gear, *D*, meshes with gear, *F*, on the countershaft, and power is transmitted through the shaft and pinion, *P*, which is in mesh with gear, *E*. The ratio of this gear system is 8 to 1. On the intermediate speed, sliding gear, *D'*, meshes with pinion, *F'*, on the countershaft, and the power is conveyed to the driving shaft through pinion, *P*, and gear, *E*, as before. The ratio of this combination

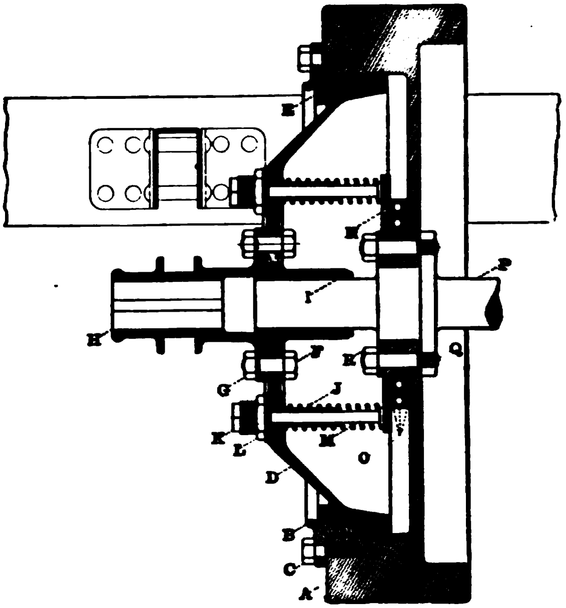


FIG. 302.—Detail Section of the Pope-Toledo Clutch. The parts are: A, fly-wheel; B, clutch ring; C, clutch ring screw; D, clutch cone; E, clutch leather; F, clutch bolt; G, clutch bolt nut; H, clutch sleeve; I, clutch sleeve bush; J, clutch spring; K, clutch spring plug; L, clutch spring plug nut; M, clutch spring stem; N, clutch spring plate; O, ball thrust collar; P, crank shaft; Q, fly-wheel stud; R, fly-wheel stud nut.

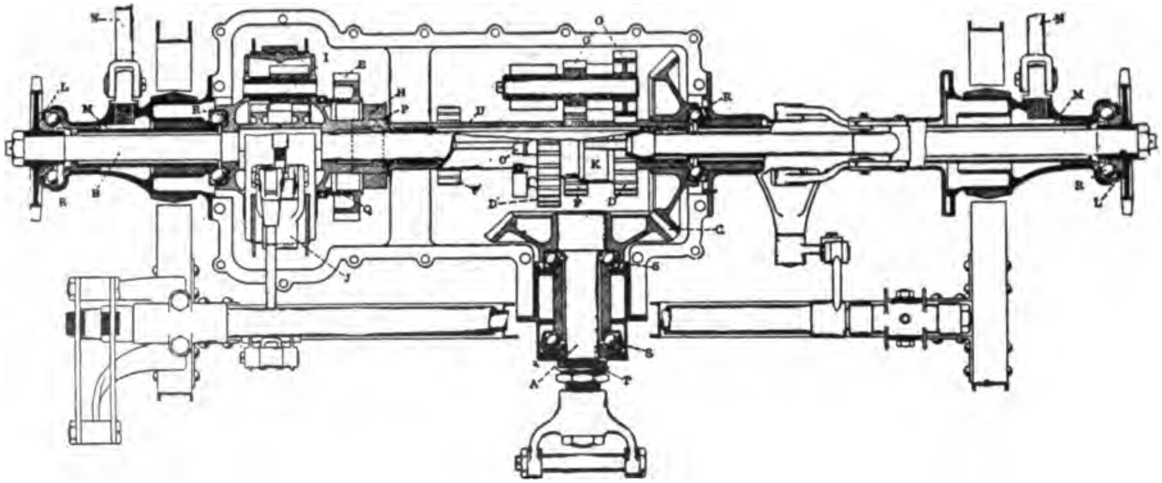


FIG. 303.—Diagram of the Transmission of the Pope-Toledo Car. The parts are: A, drive shaft; B, jack shaft; C, mitre gears; D, sliding gears; E, differential clutch gear; F, countershaft gears; G, reverse gear; H, differential clutch; I, differential gears; J, differential brake; K, sliding gear fork; L, adjusting cup; M, adjusting sleeves; N, radius rod; O, sliding clutch; P, countershaft pinion; Q, differential clutch spring; R, S, ball races; T, adjustable nut; U, sliding gear sleeve.

is 5 to 1. In reversing, sliding gear, *D*, is meshed with pinion, *G*, and power is transmitted through the reverse shaft and pinion, *G'*, and gear, *F*.

In driving on the high speed, the only gears in mesh between the motor and the driving wheels are the bevel gears, *C*. This is accomplished by sliding the gear set, *DD'*, to the left until its miter teeth, *O*, are in mesh with those on hub, *H*. This movement also pushes gear, *E*, to the left sufficiently to disengage miter gears on its hub from those on *H*, thus releasing the countershaft and establishing a positive connection between sleeve, *U*, and the differential. On returning to the lower speeds, spring, *Q*, again establishes a positive driving relation between gears *E* and hub *H*.

FIG. 304.—Columbia Four-cylinder Tonneau Carriage.

Further reference to the drawing of the transmission will show that ball bearings are used extensively, the bearings being unusually long, while every opportunity for close adjustment is afforded by the construction.

The Columbia Carriages.—Among recent American cars modeled on French lines are the 24 and 36 horse-power 4-cylinder Columbia tonneau vehicles. The engines are notable for efficiency, and for the fact that all valves and other parts are readily detachable, when necessary, without the use of tools of any kind. The inlet valves are secured by a locking device similar to that used on the breech-blocks of large rifled guns; a ⅛-turn of the handle enabling removal. Transmission is by longitudinal shaft, connected by bevel gears to transverse countershaft. A cone clutch connects speed gear to flywheel, as in typical French cars. The change-speed apparatus is of sliding gear type, gears being cut to coarse pitch to facilitate engaging, giving four forward speeds and one reverse.

FIG. 305.—Elevation of Chassis of the Columbia Four-cylinder Tonneau Carriage.

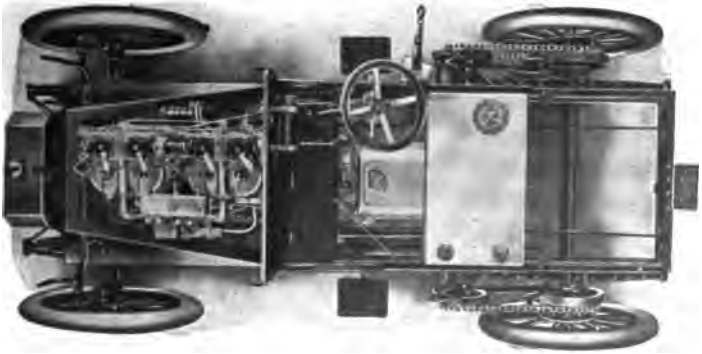


FIG. 306.—Plan of Chassis of the Columbia Four-cylinder Tonneau Carriage.

A single lever slides all gears, including reverse. It operates in a gridiron quadrant equipped with a hinged latch, preventing engaging the reverse accidentally. An interlocking device also obliges throwing out of the clutch before changing speeds.

In construction and operation, this gear closely resembles the Cannstadt-Daimler already described, having a lever arranged to move laterally, as well as backward and forward, thus shifting one single and one double-faced gear on the square separate section of the main shaft. Unlike the former apparatus, however, the highest forward speed is obtained by sliding the third speed gear forward, so as to cause it to engage, by a claw clutch device, the constantly meshed driving pinion of the main shaft, thus making the two pairs of the main shaft continuous and driving direct from the clutch shaft, as in the Decauville, Darracq, Locomobile, Peerless and Packard transmissions. The reverse is accomplished by swinging an idler pinion of broad face between the two low-speed gears, set in neutral position, as in the Daimler transmission already described.

FIG. 307.—Columbia Light Tonneau Touring Car.

The drive wheels turn loose on rear dead axle, driven by chain and sprocket from extremities of countershaft, each sprocket carrying drum of main brakes. Auxiliary brakes are attached to rear wheel hubs. The countershaft turns in plain bearings. The differential gears may be locked, so that, in event of a broken chain, the car may be driven on one wheel.

A light vehicle of this make, driven by a double opposed cylinder engine, 5x4½, set over the front axle in a conventional bonnet, and developing between 12 and 14 horse-power, has an interesting variety of control system, as shown in the accompanying diagram. As in several other American carriages, the transmission is by a longitudinal shaft and bevel gears to the differential drum.

The clutch control foot pedal, to the left of the steering post, opens the friction clutch when pressed down and closes it when allowed to rise. It is fixed on a shaft having a small finger interlocking the foot brake lever on the right of the steering post, so, that, when the clutch pedal is pressed down, no effect is created upon the brake pedal. But owing to a pin projecting in front of the small interlock on the clutch shaft, when the brake pedal is pressed down the clutch pedal is caused to go back and release the clutch. The brake connections run to the rear and

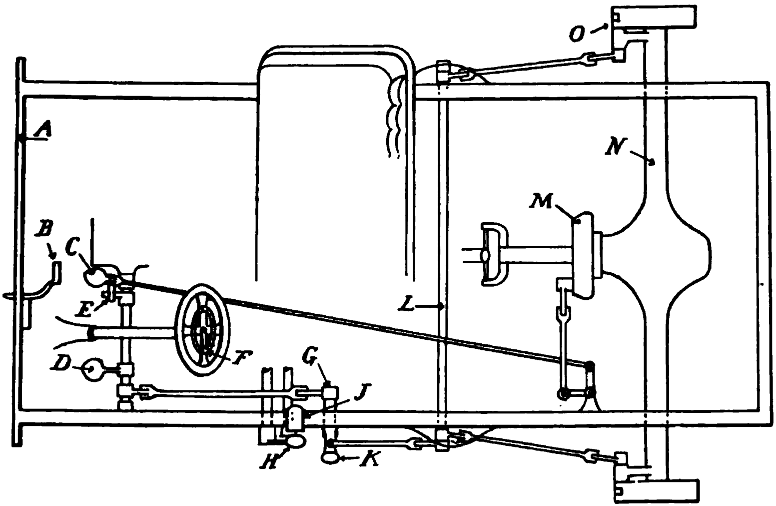


FIG. 308.—Plan Showing Lever and Control System of the Columbia Two-cylinder Light Carriage. A is the dash; B, foot accelerator lever for controlling engine; C, foot brake lever; D, clutch lever; E, clutch interlock, requiring that clutch be thrown before brakes are set; F, ignition-timing lever on steering wheel; G, clutch interlock; H, second and third speed lever; J, first speed and reverse lever; K, hub emergency brake lever; L, brake rocker; M, expanding brake on driving shaft; N, rear live axle; O, hub brake.

connect by a bell crank lever to the expanding brake band on the transmission shaft. This brake is applied beyond all the universal joints on the propeller shaft. so that they receive no braking strains.

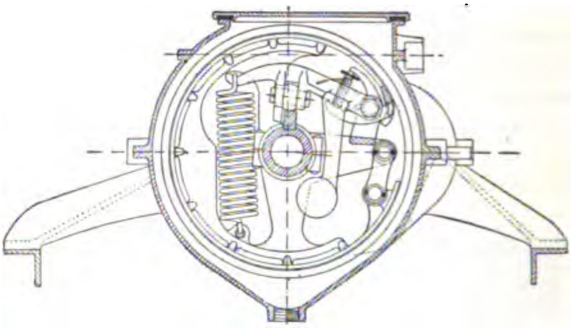


Fig. 309.—Mechanism of the Expanding Band Clutch of the Columbia Light Car.

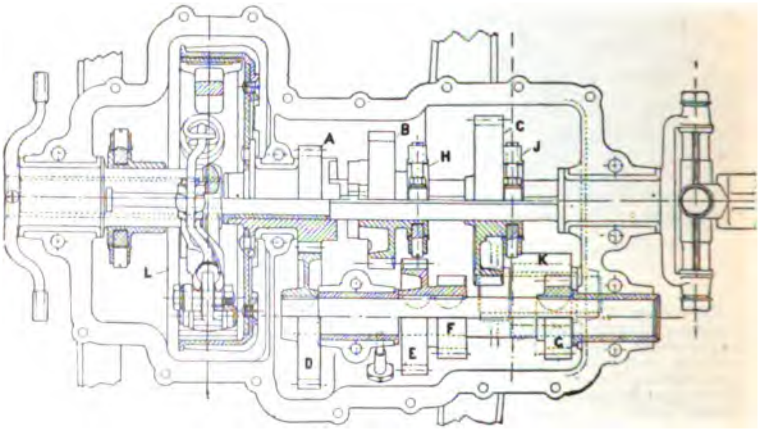


Fig. 310.—Transmission and Clutch of the Columbia Light Car. A, spur gear on the clutch shaft; B and C, spurs on the squared second shaft, the first shifted by fork hung at H, by lever, H (last figure), the second by fork at J by lever, J. D, E, F, G, three-speed pinions keyed to countershaft; K, pinion giving reverse when in mesh with C and G; L, clutch.

The emergency brake, to the left, also connects to the clutch pedal by a slip interlock, so that when it is pressed down, the clutch pedal is also pulled off. Its connections run aft and connect to band brakes on the driving wheel hubs.

The gear change control is shown on the left side directly in front of the emergency brake lever. In practice, the latter is outside of the vehicle seat, while the gear change levers project up inside of the seat. As in this vehicle the engine power is very high in proportion to the weight of the vehicle, ordinary service requires that the middle and the high gears are the only ones used. They are thus controlled by one handle which is made conspicuous. For such backing and filling as is necessary in turning in close quarters, another handle gives the reverse and low gear ahead. To set the medium gear, the conspicuous handle is pulled back as far as it will go; for the high speed it is to be pushed ahead as far as it will go regardless of notches or other indexes. A small snap indicates the off position. Similarly, to set the back gear, the second lever is pulled back as far as it will go, and, to set the low gear ahead, it is pushed forward to the end of the slot. One lever cannot be moved unless the other is in the off position. This makes the control very simple and avoids a possibility of injury to any one of the gears, and, as will be noticed, also gives the great advantage of being able to get to zero from any one gear without having to engage any other.

The motor accelerator is operated by a small foot lever projecting from the dash. By pressing it down the throttle is opened beyond the governing position and maximum power is obtained.

Under normal conditions this pedal returns to the governing position. Small teeth hold it in any accelerated position desired. For very low engine speeds, such as are desired when the vehicle is standing, the pedal is trapped to the left by the foot, so that it springs up beyond the governing position to a small but fixed throttle opening. This is adjustable, so that for standing speeds as low as 100 revolutions are possible.

The Duryea Carriage and Control.—The well-known Duryea carriage is notable for several original and exclusive features of construction. Unlike the typical automobile or horse-carriage, it is built entirely without an underframe, the wheel axles, front and rear, being connected direct to either end of the heavily built body. The principal advantages claimed for this "reachless construction" are that extra weight and complication are saved, while greater compactness and accessibility of parts are rendered possible. As shown in an accompanying cut, the three-cylinder motor already described, is placed beneath the driver's seat with the change-speed gear and other moving parts. This change-gear, or "power drum," as already explained, allows two forward speeds and a reverse, although all ordinary driving is done on the high speed, the parts of the power gear being stationary with relation to each other, and the speed of the carriage being controlled entirely by throttling.

The Duryea Transmission Gear.—The transmission gear used on the Duryea carriages, shown in section and part plan in the accompanying illustrations, is operated entirely by friction clutches, entirely avoiding the wear and constant danger of breakage involved in the use of shifting gears. The small gear, *A*, is secured to the motor shaft against the flywheel flange by screw threads. Meshing with it are three planet or idler gears marked *A′*, which are journaled upon studs provided on a triangular frame to receive them. This frame is journaled upon an extension of the motor shaft, the planet gears being held concentric with the driving gear, *A*, and is double, one part being formed integral with the studs and the other part attached to the studs

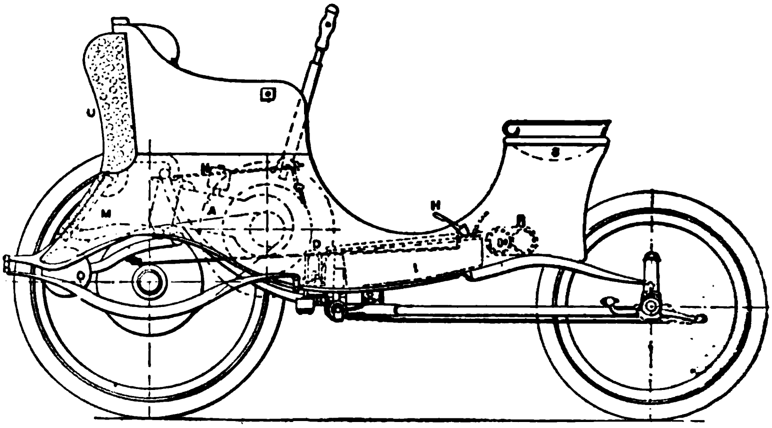


FIG. 311.—Elevation of the Duryea Three-cylinder Car. A, the motor; D, the magneto generator; H, brake pedal; I, gasoline tank; M, tubular panel for passage of water from tank, V, to water jacket; N, oil cup on motor; O, muffler; R, 6-cell battery; S, extra seat in front; U, cellular water tank, cooled by draft deflected by wings from side of vehicle.

by nuts on their projecting ends. This latter part carries the reverse ring, *H*, while both parts of the frame form supports for the clutch pins, *P*, and their actuating levers, *M*, of which the functions will be described later. Encircling the planet gears, *A′*, is an internal gear, *X*, attached to the slow-speed ring, *B*, which is supported upon the disc, *E*, by projecting lugs; while the disc, *E*, in turn, is journaled so as to remain concentric with the motor shaft, and thus support the internal gear, *X*, in concentric relation and proper alignment with the other parts. Friction bands, not shown, are attached to the framework of the vehicle and encircle the rings, *H* and *B*, being provided with levers by which either band may be caused to grip its corresponding ring at the will of the operator. If the reverse ring, *H*, is gripped by its band, the planet gear studs, with the attached framework, will be held stationary and the motion of the motor will be transmitted from the gear, *A*, through the planet gears, *A′*, to the external ring, driving same in a reverse direction, as shown by the arrows in the plan. If the slow-speed band is gripped upon its ring, *B*, the

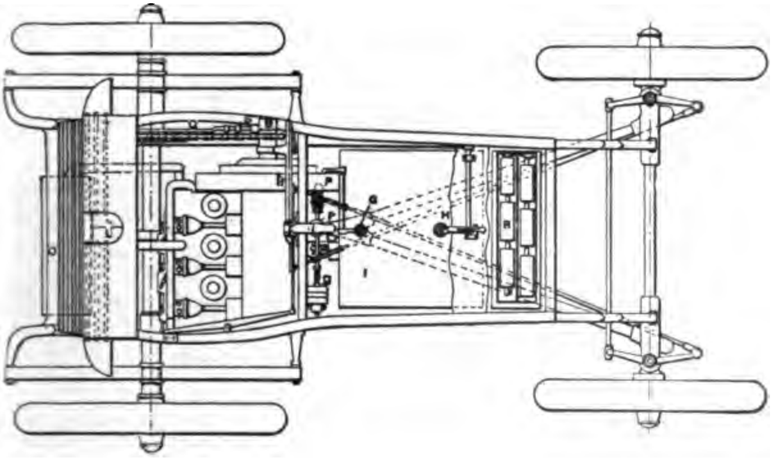


FIG. 312.—Plan View of Duryea Three-cylinder Car. B, bearing for speed gear; C, distance-rod from rear axle for taking up the pull of the chain; D, the magneto-generator; G, pedal for operating the reverse clutch; H, brake pedal; I, gasoline tank; P, central single control lever; R, 6-cell battery. Front axle shorter than rear to prevent skidding and promote ease in turning.

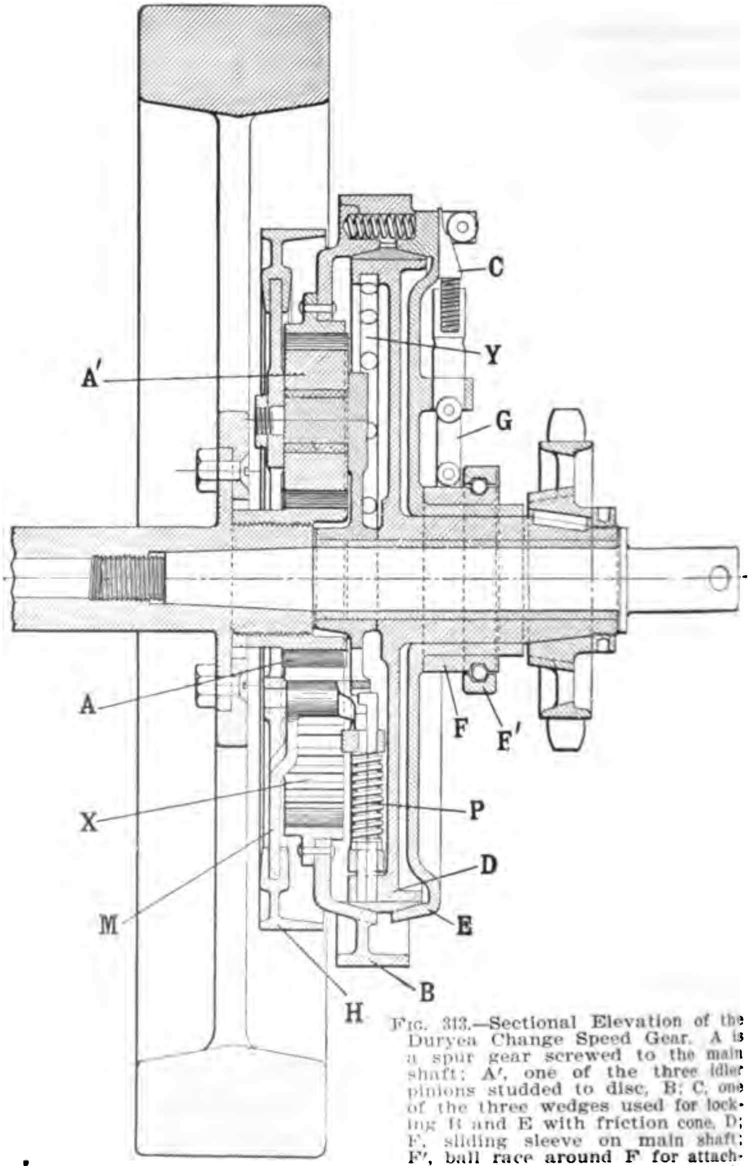


FIG. 313.—Sectional Elevation of the Duryea Change Speed Gear. A is a spur gear screwed to the main shaft; A′, one of the three idler pinions studded to disc, B; C, one of the three wedges used for locking H and E with friction cone, D; F, sliding sleeve on main shaft; F′, ball race around F for attaching the shifting lever; G, toggle joint operated by shifting sleeve, F; M, lever for raising or lowering pin, P; X, an internal gear on disc, B; Y, a groove containing perforations for admitting pins, P, when H and B are locked together.

internal gear will be held in a fixed position and the motion of the motor will cause the planet gears, *A′*, to roll around inside the internal gear in the same direction as the gear, *A*, carrying the studs of the planet gears, *A′*, with their framework, slowly in a forward direction, as will be explained later. If all parts are locked together in any convenient manner so as to prevent relative motion, they will then move with the motor and cause the driving sprocket to move at high speed forward, while if no clutch is in engagement the motion of the motor will turn the gears idly without producing motion of the sprocket.

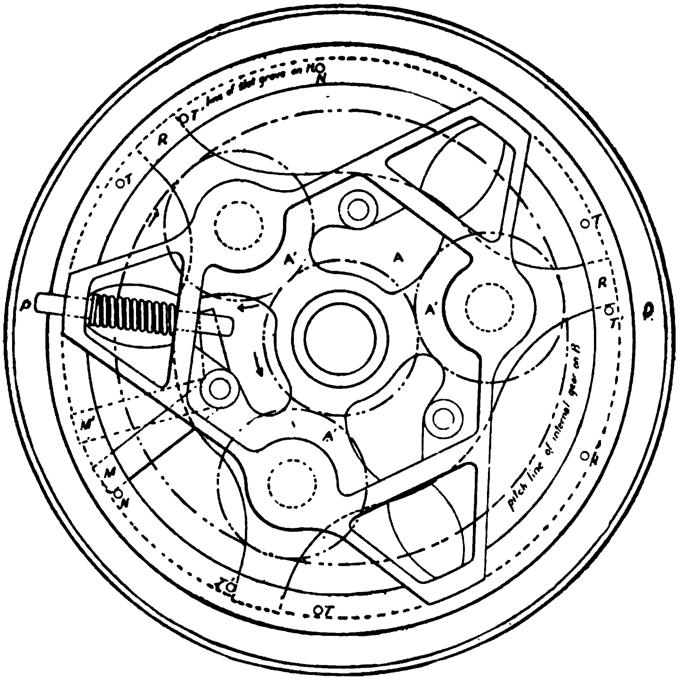


FIG. 314.—Front Elevation of the Duryea Change Speed Gear. The lettering here refers to the same parts as in the previous figure. N marks the position of the lever, M, when pins, P, are inserted in holes, Y, in D. M′ marks the position of lever, M, when pins, P, are raised from holes in D. R and R, arms of the spider, carrying the three idler pinions, A′, and sliding in a groove on H to the pins, T and T′.

More specifically, these various motions are accomplished as follows:

The planet-gear frame is *normally* held in engagement with the sprocket-carrying disc, *D*, by means of the pins, *P*, so that holding the internal gear, *X*, by means of the slow-speed band—the other clutches being released—it carries the sprocket forward at slow speed. Since the planet-gear frame and the disc, *D*, are normally in engagement, it is evident that clutching the ring, *X*, to the disc, *D*, will prevent relative motion of the planet gears and the internal gear, and thus cause the sprocket to be carried at the speed of the motor. This effect is produced by means of conical friction surfaces on *D*, engaged by complementary surfaces inside the ring, *B*, and the disc, *E*, which surfaces are brought in contact by means of the wedge, *C*, bearing against the disc, *E*, under the roller attached to the lug projecting from the ring, *B*. This wedge, *C*, is operated by a shifting collar, *F*, and toggle link, *G*; a shifting lever, not shown, being attached to the outer ring of the ball bearing, *F′*. The section shows these surfaces in engagement; releasing being effected by moving the shifting collar, *F*, toward the sprocket, which withdraws the wedge, *C*, and permits the friction surfaces to be separated by the spring shown. The large surfaces and the toggle and wedge arrangement for closing them, secure a very powerful pressure with little shifting effort, while the disc, *D*, is ordinarily surfaced with brass, which, having a higher expansion co-efficient than the cast iron against which it bears, is rapidly heated, in case of slipping, and becomes self-tightening by expansion. Releasing all the clutches allows the sprocket with its disc, *D*, and the planet-gear frame to stand idle while the internal gear revolves freely in a reverse direction, as shown by the arrows, although the motor may be running.

The reversing effect is secured by holding the ring, *H*, which is mounted on the arms of the planet-gear frame, in such a manner that the frame may move a short distance before it is stopped by pins, *T′*, which motion moves the lever, *M*, into the dotted position *M′*, and withdraws the pin, *P*, from engagement with the disc, *D*, thus separating the planet-gear frame from the sprocket disc, *D*. Since the pins, *T′*, prevent further movement of the planet-gear frame, while the disc, *D*, is free to move in any direction, it is evident that the motion of the motor will drive the internal gear, *X*, in the reverse direction, and that clutching the gear, *X*, to the sprocket disc, *D*, by means of the high-speed clutch, will cause the sprocket to be carried in the reverse direction along with the gear, *X*. It is further evident that releasing the high-speed clutch will stop the reverse movement of the sprocket, while releasing the reverse ring, *H*, will permit the pins, *P*, to resume their normal position, under the action of their springs.

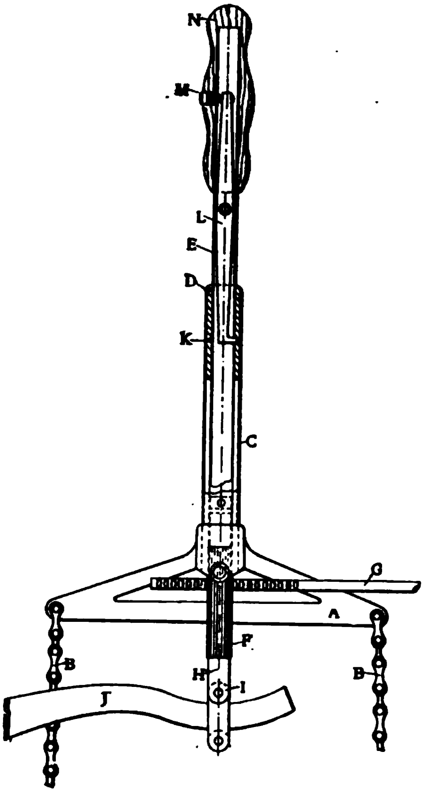


FIG. 315.—Central Control Lever for Steering, Throttling and Operating the Clutches. When arm, J, is raised by an upward movement of handle, N, the low clutch, is set; when depressed, the high clutch is set; in neutral position, both are thrown out. The reverse is operated by a foot pedal.

The whole device is placed by the side of the motor, on a short extension of the motor shaft, and the power is transmitted from the driving gear,. *A,* to the various clutch surfaces, in approximately a single plane, which lessens the torsion strains and gives great strength with little weight. All parts are concentric or balanced, and, therefore, adapted for use at high speeds.

The most interesting feature of this carriage is the single central controlling lever, by which the three different functions of driving the vehicle—steering, throttling and setting the clutches—are easily and readily performed by one hand. It consists of a casting, *A*, pivoted on the forward edge of the seat to swing sidewise. It has oppositely projecting arms below the seat to which the tensile steering connections, *B B,* are attached, while upward and slightly forward the tube or lever proper, *C,* projects. Bushings, *D D,* at each end support a smaller tube, *E,* within the main tube, which smaller tube slides up or down and carries at its lower end a long pinion, *F.* This pinion engages (substantially in the axis of the pivot) a rack, *G,* having diamond shaped teeth which permit the lever to be swung to the extremity of its motion in either direction without damaging the teeth of the rack and permitting the rack to be operated by rotating the pinion, *F*, in any position. This rack is attached near the right-hand side of the wagon, while the other end of the lever operates the throttle slide. The pinion is bored out, and in it is swiveled a stud, *H*, carrying rollers, *I I,* which engage the shifting lever, *J,* so that sliding the internal tube, *E,* up or down carries the shifting lever, *J,* up or down with it, and permits setting the clutches, while in no way interfering with either the steering or the throttling. The end of the shifting lever is bent to the arc described by the rollers in their normal working position, and any slight variations are readily provided for by the hand of the operator. The upper bushing, *D,* on the steering lever is provided with an internal groove, *K*, while the internal tube has in it a lever, *L,* with a projecting end adapted to engage this groove and lock the tube, *E*, in the middle position with the clutches off. By pressing the safety button, *M,* in the handle, *N*, this catch may be disengaged to permit setting either the high or low speed clutches.

This controlling device being centrally placed permits the operator to sit on either side of the vehicle. The design of the steering mechanism is such that it is irreversible and will run over an obstruction "hands off" without perceptible deflection from the course. This fact relieves the controlling lever from all unpleasant vibration, and no muscular effort is needed to hold the vehicle in its course. A slight pressure on either side of the lever will deflect the vehicle. It is therefore possible to steer with the thumb and finger, and throttle by twisting the handle. The central position of the lever puts it out of the way in mounting or dismounting and makes it much handier than any other possible position of the controlling device.

FIG. 316.—Oldsmobile Six-horse-power Runabout.

The Oldsmobile and Control.—The popular Oldsmobile is a typical form of the reachless side-spring construction, also adopted by the Knox and other light and medium weight American gasoline carriages. The underframe consists of two 6-leaf longitudinal side-springs, each 5 feet 6 inches long, arranged parallel at a distance of 30 inches; rigidly secured to axles at either end. The motor and moving parts rest on three-sided angle steel frame or central horizontal portions of the springs below and within body of carriage. This arrangement gives

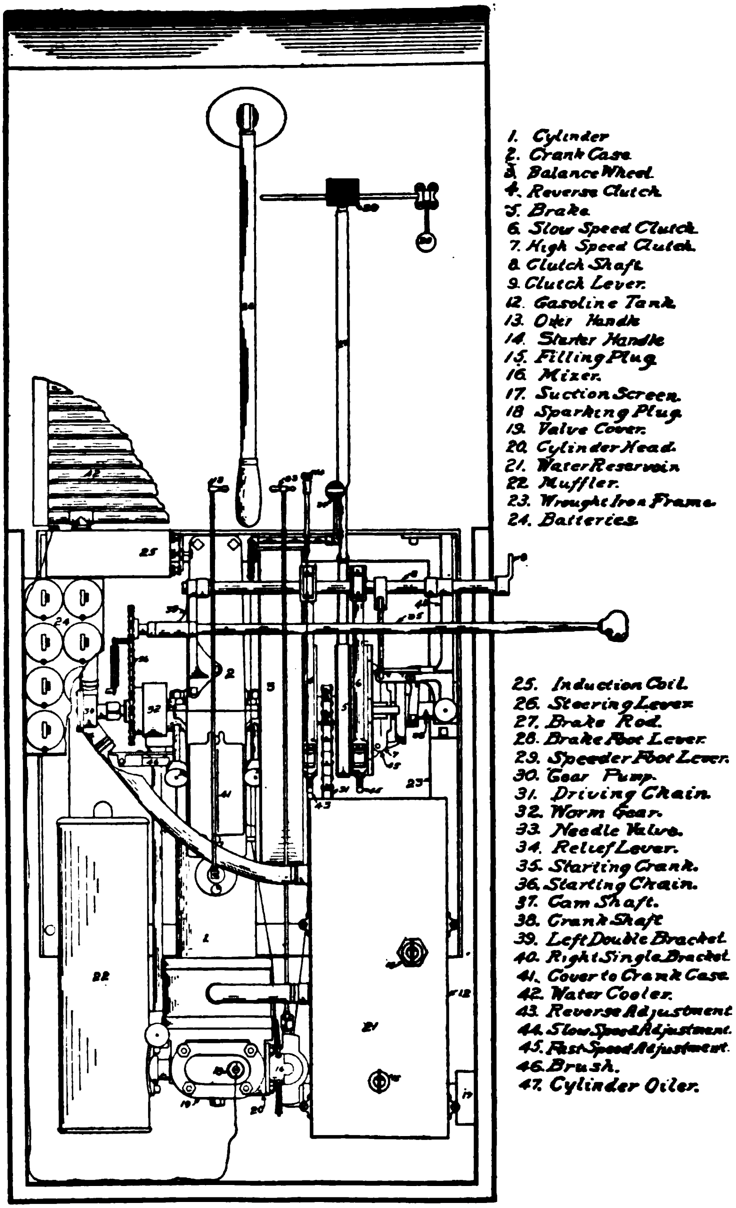


FIG. 317.—Plan View of Oldsmobile Body and Controlling Apparatus.

great distortability, enabling the carriage to take uneven roads without jar or inconvenience, better than with many patterns of swivel-jointed tubular frames.

The horizontal one-cylinder engine is set midway on the central support of the side-springs, with the change-speed gears on the main shaft. The water-circulation system is controlled by a rotary pump operated from the shaft through a flexible joint, which preserves it from shocks due to motor pounding. The radiating tubes are arranged in two horizontal layers across the carriage, water being drawn from the lower to the upper row by the pump; the cooling being effected without the use of fins or ribs, as in most other forms of tubular radiator. The starting crank, fixed permanently on outside of carriage body, turns shaft parallel to and at the rear of clutch shaft. Transmits rotary movement to main shaft through chain and sprocket. When the engine turns over under its own power, the starting shaft is automatically thrown out, and ceases rotation.

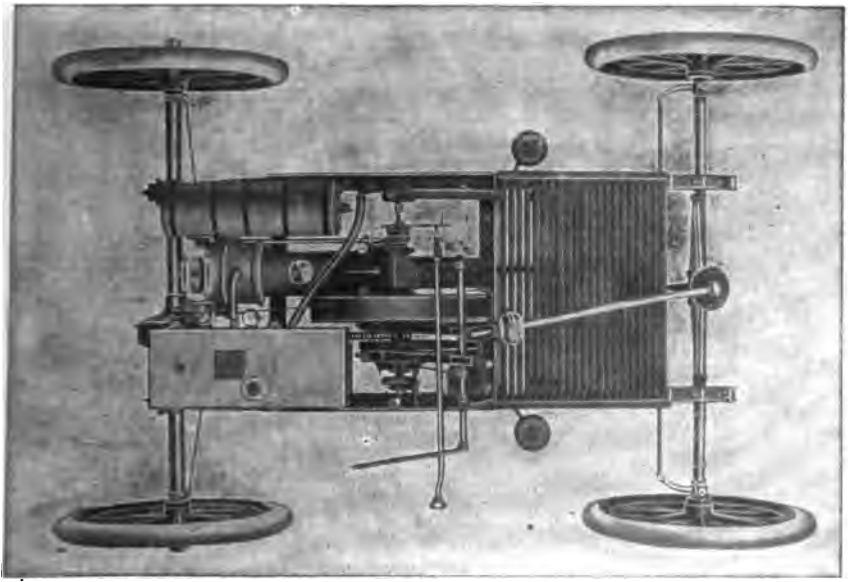


FIG. 318.—Plan of Chassis of Oldsmobile.

Transmission is directed by chain and sprocket connections from the main shaft, through the two-speed planetary gear. This apparatus consists of two band-clutch drums, internally geared; actuating planetary pinions; one giving low speed, the other the reverse movement. The high speed is obtained by throwing in a sliding bevel friction clutch at the end of the shaft, thus driving the sprocket direct from the engine shaft. The gear is operated from a simple clutch shaft, having a three-throw cam arrangement, throwing either forward speed or reverse by movement of one handle, through rotation from reverse, to low speed, to high speed; but from high speed direct to reverse, low speed not engaging; brake bands lock and unlock automatically in this order. The main brake drum set on the shaft with speed gear drums, is operated by a pedal on the floor of the carriage. There is an auxiliary brake on the differential drum, for checking rotation of the road wheels in case of chain-breakage. The transmission chain is tested by a straight pull of 4,000 pounds.

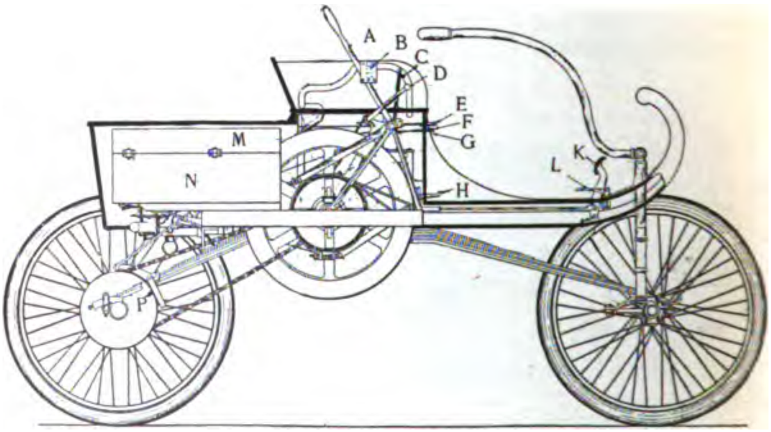


FIG. 319.—Sectional Elevation of the Oldsmobile Runabout. A, the speed shifting and reversing lever; B, the battery switch; C, the spark-controlling lever; D, the starting crank; E, starting handle; F, oiler handle; G, needle valve; H, relief lever; K, brake foot lever; L, speeder foot lever; M, water reservoir; N, gasoline tank; P, brake drum on rear wheel hub.

The Oldsmobile Transmission.—The two-speed and reverse transmission of the Oldsmobile is of the planetary gear type. The reverse and low speed forward are operated by band and drum clutches, and the high speed forward by a friction compression clutch. A single shaft carrying three eccentrics, with the throws in different directions, serves to actuate all three—the two former, by tightening bands around the brake drums, the latter, through a bell crank moving in a direction longitudinal to the main shaft. As shown in the sectional diagram, two spur gears are keyed to the main shaft. Each of these gears meshes with planetary pinions studded to a frame or spider arranged to turn with a sleeve loose on the shaft. Furthermore, the pinions mesh with internal gears, so that the entire system may rotate at once,

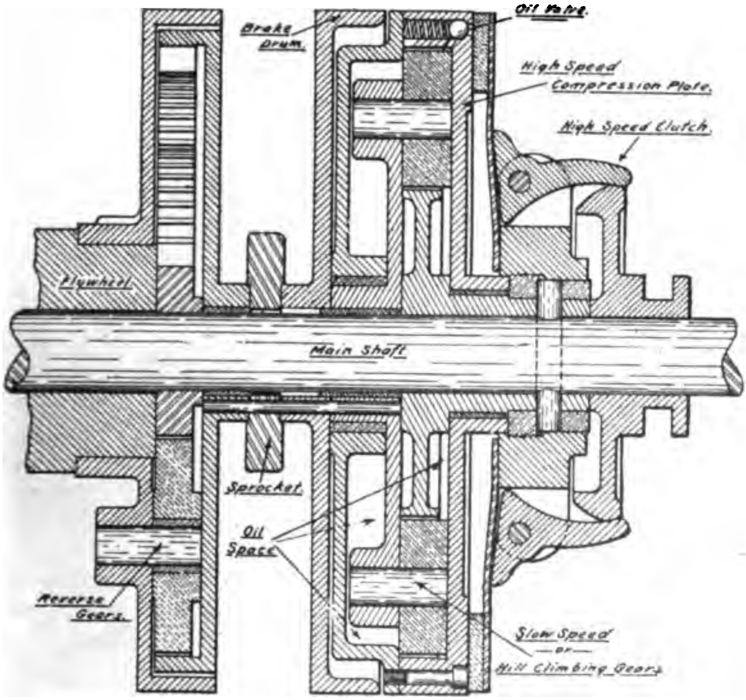


FIG. 320.—Section of Oldsmobile Two-Speed and Reverse Transmission.

or the planet pinions may turn on their axes over the internal gears. Close examination of the section will show that the internal gear of the reverse, the sprocket, the main brake drum and the pinion frame of the forward gear are rigidly held together by a pin, so as to rotate as a unit. When neither of the bands is applied the rotation of the two spurs on the main shaft is transmitted through the planetary pinions to the brake drums, leaving the driving apparatus stationary. The reason for this is obvious for, since the internal gear of the reverse and the pinion frame of the forward speed are rigidly connected on one sleeve, they obviously cannot rotate in opposite directions. When, however, the band is applied to the forward speed clutch drum, which is the internal gear, the spur causes the pinions to rotate on their axes and travel around within the internal gear, imparting rotative movement in the opposite direction to their frame and the sleeve holding the sprocket and the internal gear of the reverse. The clutch drum of the reverse gear is the pinion frame, and this being held rigid by the band, the driving spur rotates the pinions on their axes, causing them to drive the internal gear and the sprocket in the same direction as its own rotation, thus reversing the movement of the carriage. The high speed forward is obtained by throwing in the cone friction clutch shown at the right of the diagram, the effect being to press upon the high speed compression plate, thus holding the pinion frame and internal gear in rigid relation, and causing the entire transmission system to rotate as a compact whole at the speed of the main shaft.

The shaft carrying the cams for locking and unlocking the clutch bands and the high-speed cone, is handled by means of a single lever, the rotation being from reverse through slow speed to high speed, but on returning the slow speed does not engage and thus the lever may be thrown direct from high speed to reverse, so that this gear may be used to aid the brake in case of emergency.

The Stevens-Duryea Carriage.—The Stevens-Duryea carriage is a peculiarly American product in all its lines of design, no trace of French influence being discernible. Indeed, like the three-cylinder engine Duryea cars, it represents the finished product—in a somewhat different direction— of the nearly twenty years of experiment conducted by those pioneers of American automobilism, the Brothers Duryea. The motor, change-gear and other apparatus are included in the body of the carriage, and every means for attaining the ends of compactness and simplicity of operation seem to have been adopted. A common steering

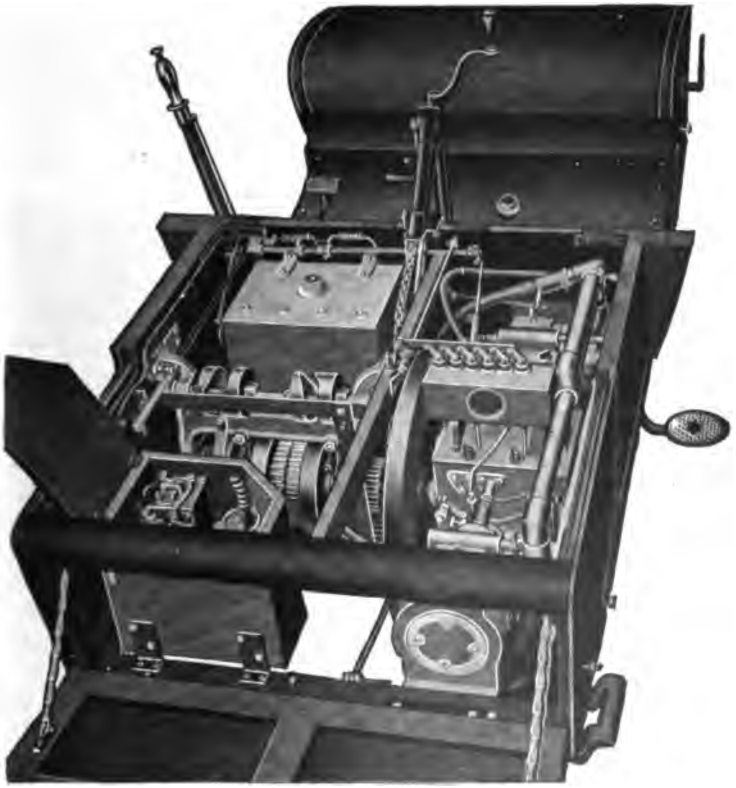


FIG. 321.—Motor and Control Apparatus of the Stevens-Duryea Car. Starting by horizontal crank; steering by upright crank; speed shifting by hand lever at left; throttling by button at end of upright lever.

and motor starting pillar is fixed at the centre of the seat; both functions being controlled by hand cranks. The speed-changing and throttling lever is set at the left hand of the driver. By moving this lever forward or backward a rack is moved, which, through a spur-gear rotates a camshaft and sets clutches controlling three forward speeds and one reverse. In addition to the cam shaft, operated by this rack and pinion movement, are two others, known respectively as the top and speed shafts.

"The top gear shaft is substantially an extension of the motor crankshaft and carries the clutch hubs keyed to it, all three speed-change gears being loose on the top shaft. The reverse gear sprocket on the top shaft is also loose, and its chain drives a loose sprocket on the lower or speed shaft, which can be engaged by a splined solid-jaw clutch, actuated by a treadle from the driver's footboard. The top or gear shaft is provided with two double-acting friction-clutch shells, fixed respectively to the three cast iron gears and the backing sprocket, and the two cam-actuated clutch levers can clutch any one of the four loose elements to the gear shaft. The speed shaft has keyed to it, in addition to its backing sprocket clutch, three rawhide gears of different diameters, meshing with the cast iron gears on the top shaft; by this arrangement the speed shaft is driven at will at different rates, giving the wagon three speeds forward and one backing speed. Owing to the peculiar construction of the cams carried by the cam shaft, no two friction clutches can be thrown into engagement at the same time, hence no mistake can be made in handling the speed-change lever."

The Cadillac Carriage.—The Cadillac gasoline carriage is an American product, combining a number of original features. Its first introduction was in 1903, and since that time it has been built on substantially the same lines. The single-cylinder motor has already been described in the preceding chapter, and no tendency has since been shown to use a double cylinder. It seems to have made good the claims of its manufacturers in combining good balance and efficiency in operation.

As shown in accompanying figures, the machinery and control apparatus are very compactly arranged, and a good idea of the convenience of operation may be obtained. The body frame is of angle-steel, hot riveted and trussed at four points by transverse bars. The motor and transmission gears are hung at the centre of the frame, and the driver's seat is placed directly above. As shown in the cuts of plan and elevation of the Chassis, the arrangement of the control apparatus agrees with that of the standard carriages already described. Here the steering wheel

(20) carries a quadrant (24), around which works the throttle lever. This lever is fixed at the end of a rod set parallel to the steering pillar, and actuates an arm (22) below the floor, connected by a link (23) to the throttle arm, and moves the cam (25) as already explained in connection with the figure of the engine. By this means the volume of the charge may be constantly regulated. The spark lever, (15) set at the right of the driver's seat, furnishes another means of regulating the engine, advancing or retarding the spark. The top speed and reverse are operated by means of the hand lever (16), while the slow speed is attained by the pressure on the pedal (34) at the left of the steering pillar. The pedal at the right acts upon the main brake on the differential drum. When it is pressed upward and forward, it rotates the short transverse shaft to which it is attached, causing an arm to rise and exercise a pull upon a double cable, thus constricting the two brake bands on the differential drum. The reverse gear may also be used as an extra brake, as will be presently explained.

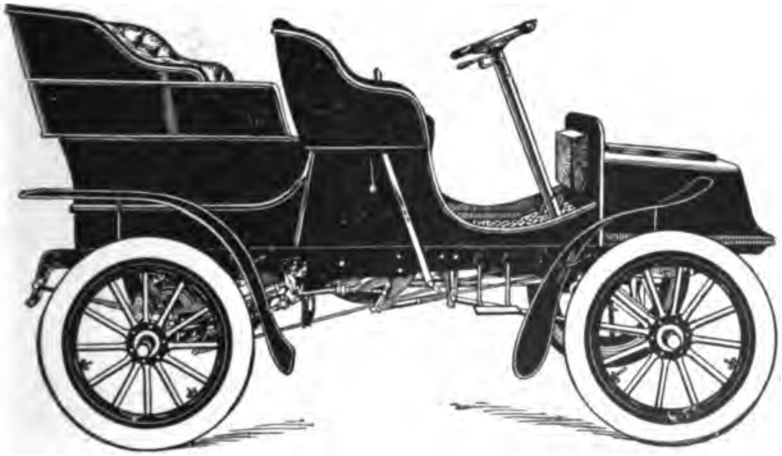


FIG. 322.—Cadillac Car, with Rear Entrance Tonneau.

The Transmission.—The transmission used on this car is of the planetary type, its theory and operation being readily understood from the accompanying figure. As here shown, it consists of the two drums, *H* and *K*, the former of which is the reverse drum, and contains six studs, *L*, holding six spur pinions. Three of these pinions, *E*, are twice the width of the other three, *F*, and all mesh with pinion, *G*, which is of the width of the *F* pinions, and is on a sleeve keyed to the hub of the drum, *K*. The main driving pinion, *D*, is keyed to an extension of the crank shaft, and meshes with the *E* pinions only, on tne widened portion which projects beyond the pinions, *F*, as shown in the cut. The left end of the gear case, *C*, is fastened to *H* by screws. The drum, *B*, on which is the internal gear, is continued through

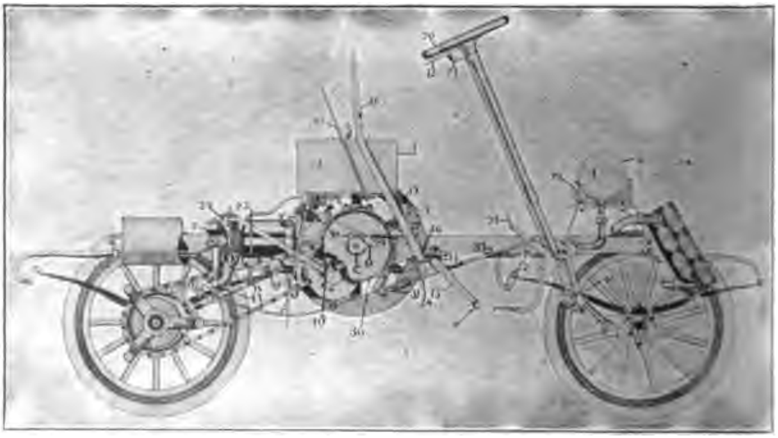


Fig. 323.—Sectional Elevation of the Cadillac Chassis, showing operative and control apparatus, as explained in text.

the casing, and the sprocket, A, forms part of it. When the brake drum, *H*, with the pinion studs upon it, is held stationary by a band brake; and when pinion, *D*, turns with the shaft in the direction of the arrow upon it, it drives pinion, *E*, in the direction shown by its arrow, and, since *E*'s stud is stationary, *E* in turn drives internal gear, *B*, in the opposite direction. This produces the reverse. To obtain the slow speed, the brake drum, *K*, is held by a brake band, and pinion, *D*, drives pinions, *E*, as heretofore. *E* in turn drives *F*, but as *G* is stationary, since it forms part of the drum, *K*, the pinions, *F*, travel round it with a planetary motion, thus turning the drum, *H*, slowly and causing the pinions, *E*, to turn the internal gear and drum, *B*, even more slowly, but in the same direction as that in which *D* is turning. For the high speed, a leather-faced disc, keyed to the shaft, is pushed against the smooth surface on the right-hand end of drum, *K*, thus locking *K* to the shaft, and causing the whole drum to turn as one unit without any of the gears revolving. When the car is standing still and the engine is running, all the gears are turning, and the drum is revolving idly about the shaft.

It is easy to understand the method of varying the speed and

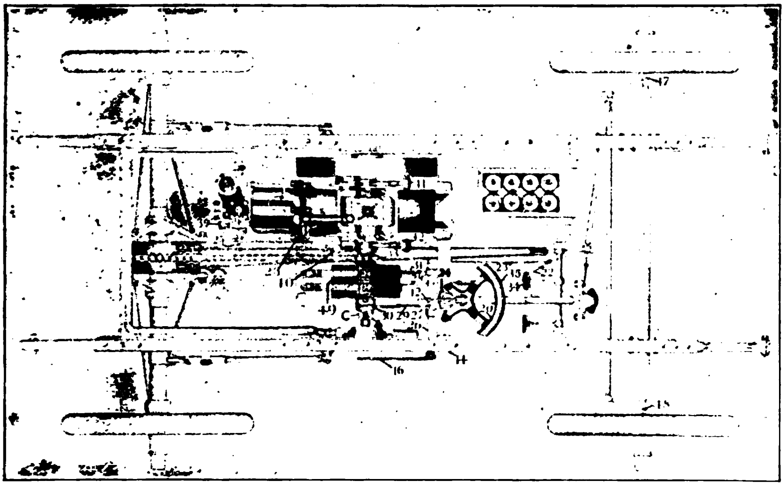


Fig. 324.—Plan View of Chassis of the Cadillac Car, showing operative and control apparatus.

power ratios by the use of this transmission. The control lever (16) is attached to the control shaft (26), which has two arms (27 and 28), on different radii. Arm 27 has attached to its end a rod (29) which engages and controls the high speed clutch (30) in the manner already explained. At the end of the other arm (28) is a rod (31), which engages and controls the reverse brake band (32). If the controlling lever be moved forward, the first arm (27) and its rod (29) cause the high-speed clutch to lock the transmission gearing together into one rotating unit, so that it revolves with the engine shaft and acts as an additional fly-wheel, carrying the driving sprocket (33) around with it. If, on the other hand, the control lever (16) be moved backward, the high-speed clutch releases, leaving the engine free to run without driving the carriage. This is the neutral position. If the lever (16) be moved still further back, the rod (31) attached to arm (28) will be drawn forward and will close the reverse brake band upon the reverse drum, *H*, as previously explained. Consequently, the sprocket turns in the reverse direction at low speed. Since the grip of the reverse band may be varied, so as to permit of more or less slip, it is possible to use the reverse as a brake for ordinary needs.

FIG. 325.—Diagram of the **Cadillac Transmision, giving two forward speeds and one reverse.**

In throwing in the low speed, the control lever is set in the neutral position, in which both the high speed and reverse clutches are released, and the slow speed pedal (34) is pushed forward and upward by the flat of the foot. When this is done the attached rod (35) is moved, and the slow-speed brake band (36) is moved upon the drum, *K*, thus causing the sprocket to revolve with the engine shaft, but at a greatly reduced rate.

The De Dion & Bouton Speed Gear.—The two-speed transmission of the De Dion & Bouton carriages consists of a hollow driving shaft, *A*, on which are two loose gears and their clutch drums, *C* and *D*, and *a* secondary shaft, to which are keyed two spur pinions, *G* and *H*. Within the hollow driving shaft, *A*, slides a round shaft, *S*, upon the extremity of which is carried a right and left-handed screw, *U*. This rod, *S*, is arranged to slide in the hollow shaft, *A*, so that the right and left-handed screw, *U*, may operate as a rack to impart axial movement to the pinions, *O*, *P*, *Q* and *R*, which are mounted on right and left threaded axles, screwing into adjustable bearings or sleeves. Consequently, as may be understood, the longitudinal movement of the screw rack, turning the pinions on their screw axles, tends

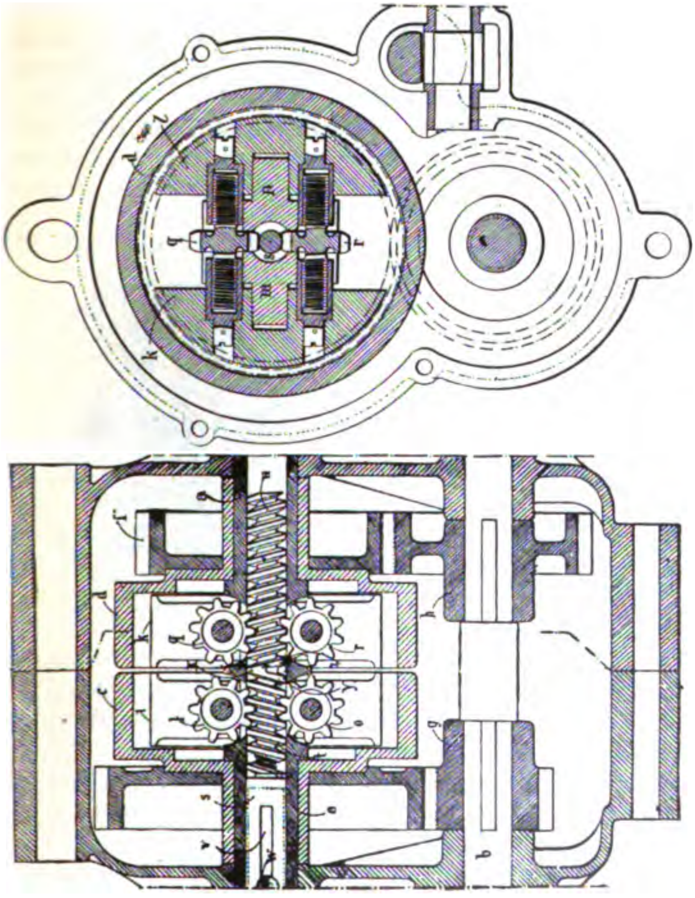


FIG. 325b.

FIG. 325a.

FIGS. 325a, 325b.—Longitudinal and Transverse Section of the De Dion & Bouton Two-speed Transmission Gear.

to force them in or out of the sleeves in which they work. The result is that the segments, *K* and *L*, also shown in the transverse section, are forced firmly against the internal circumference of the drum, *D*, clutching it and producing a rigid driving connection between the hollow rotating-shaft, *A*, causing it to carry around the entire system, including the internal rod, *S*, double screw, *U*, and the pinions, *O*, *P*, *Q* and *R*. This rotative movement is insured by the slides, *M*, *N*, with which the segments, *K* and *L*, are always in fixed relations.

The reversing gear used with this transmission is equally simple and effective in operation. As shown in the figure, *A* is the countershaft passing through the change speed gear; *B*, a spur pinion for driving direct to the differential gear, and having a bevel gear at one end engaging the bevel pinions, *C* and *D*; *E*, a bevel gear keyed to *A* at *F*; *G*, a nut holding *E* in place. *H* is a sleeve on *A*, on which gear, *B*, turns loosely. *J* and *J* and springs attached to the brake drum, *K*, and holding the bevel pinions. *C* and *D*, against the stop pieces, *M* and *M*. The reverse motion is obtained when the band, *L*, is tightened, preventing the rotation of *K* and drawing bevel pinions, *C* and *D*, from engagement with stop pieces, *M* and *M*, thus allowing them to rotate on their own axes and reversing the motion imparted by drive pinion *B* to its bevel gear end. The bevel pinions, *C* and *D*, are studded to a two-armed spider which, as shown, turns on shaft *A*.

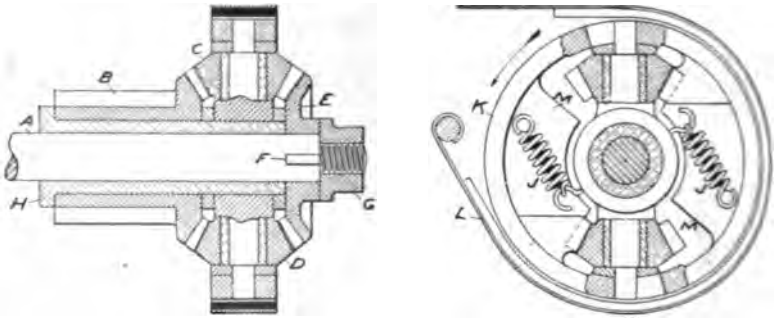


Fig. 325c. Fig 325d.

Figs. 325c, 325d.—De Dion & Bouton Reversing Gear.

CHAPTER TWENTY-FOUR.

GENERAL PRINCIPLES OF ELECTRICITY, AS APPLIED TO ELECTRIC VEHICLE CONSTRUCTION.

The Use of Electric Motors on Vehicles.—Vehicles propelled by electric motors, whose energy is derived from secondary batteries, are much preferred by many authorities on account of the combined advantages in point of cleanliness, safety and ease of manipulation. When well constructed and well cared for, they are also less liable to get out of order from ordinary causes. Among their disadvantages, however, may be mentioned the facts that the storage batteries must be periodically recharged from some primary electrical source, which fact greatly reduces their sphere of efficient operation. Since at the present time road vehicles driven by electricity are not the prevailing type, power charging stations are few and far between on the ordinary lines of travel, and it is not possible to make a tour of more than twenty-five miles, at the most, from the base of supplies. It is impossible to counteract this deficiency by carrying an extra set of batteries, since these are so immensely heavy, as usually constructed, as to greatly curtail the speed and carrying power of the vehicle. It is also impracticable to propel a vehicle by a battery of primary cells carried within it, since a battery of sufficient power to propel the vehicle would have little, if any, advantage in point of endurance over secondary cells, and when once exhausted must be entirely replaced. One or two attempts to use a primary battery on a motor vehicle have been recorded, but the great waste and expense involved must continue to render such a construction more of a toy and an experiment than a practical possibility. Some machines, particularly of European manufacture, have attempted to combine the use of electricity with the explosive motor, the latter serving the double duty of driving the carriage and charging the batteries, which may then be used to supply energy for the electric motors. It must be said, however, that such a carriage as this is heavy and complicated to a point vastly in excess of the advantages supposedly gained.

Conditions of Electrical Activity.—There are two kinds of electricity, according to the usual classification: static electricity and current electricity. As a matter of fact, however, the difference is rather a question of phenomena than of anything more fundamental. The term, static electricity, refers to the phenomena observed in the charging of a condenser, and is attributable to the fact that a body of high electrical potential imparts a portion of its energy to another having a lower potential, just as a heated body gives off a part of its heat to a cold body, equalizing the temperature. The phenomena observed in connection with the electric current differ from the "shock" of the static electricity only in the fact that the current marks a continuous passage of electrical energy from a point of high potential to one of lower potential, showing that the source of E. M. F. is constant, just as a substance in combustion constantly gives off heat. This fact is shown in all types of electrical generators, the galvanic cell operating on the principle that the positive, or high potential, pole constantly transmits its energy along the circuit to the negative, or low potential, pole.

Units of Electrical Measurement.—It may be said in a general way that the electric motor has one point of advantage over any heat engine, in the fact that it is much more flexible in operation, which is to say more easily regulated, as to speed and power efficiency. It is also possible to obtain a vastly closer approximation to theoretical requirements under the conditions of practical operation, and to estimate much more precisely the power efficiency to be obtained from a given electrical source on any given circuit. This is because the available working energy, in terms of amperes, is in exact proportion to the voltage and resistance of the circuit, as well as to the amount of efficient activity in terms of work accomplished and time consumed. As we have already seen, the power efficiency of a steam engine is estimated, in the first place, in terms of heat and power units; secondly, in terms of foot-pounds or the efficiency of the engine to move so many pounds through such a space in such a length of time; and thirdly, in terms of gauge pressure or estimated temperature. In short, the units of power are all stated in terms of pounds, feet and seconds in estimating the power passed on any given electrical circuit. The units of electrical measurement are stated in terms of length, weight and time, which is to say in terms of centimeters, grams and seconds. This gives the C. G. S. units, as they are called, which are estimated in accordance with the decimal system of measures. The units thus established are, of course, largely arbitrary—just as are all units—but they have been carefully estimated, so that the proportions between current strength, circuit resistance and voltage may be accurately maintained.

The Ohm, the Unit of Resistance.—The first unit of electrical measurement with which we have to deal is the ohm, which is the unit of resistance. This unit measures not only the relative resistance of a circuit composed of a conducting wire of a given length and diameter, as compared with wires of different length and diameter, composed of the same material, but also the specific resistance, or resistivity, which refers to the immense variations in resisting quality found between given wires of the same length and cross-section, made of different materials. The different resistivity of several different metals, as found in circuits, precisely similar in all points of dimensions, is demonstrated in the fact that, while a unit wire of silver shows a conductivity of 100, and one of copper, 99, a wire of iron gives only 16.80

The value of the ohm, as fixed by the Electrical Congress, at the Columbian Exposition in 1893, is equivalent to the resistance offered to one volt of E. M. F. by a column of mercury 106.3 centimeters in height (about 41.3 inches), and one square millemeter (.00155 square inch) cross-section, determined at the temperature of melting ice (39° Fahrenheit). Mercury was chosen for this test, because on the scale giving a conductivity of 100 to silver, it stands 1.6, while its resistivity is 99.7, as compared with 1.52 for silver; being thus very nearly unity in the first particular, and 100 in the second. One ohm is also equivalent to the resistance to be encountered in one foot of No. 40 B. & S. copper wire, which has a diameter of .003145 inch, or 3.145 mils; or to the resistance encountered in about two miles of the copper wire used in electric trolley lines. In both cases we have approximately the equivalent of the afore-mentioned column of mercury, if the test is made at a temperature of 45° Fahrenheit. In general, the resistance of a circuit varies inversely as the diameter of the wire, and directly as the length of the wire.

The Ampere, the Unit of Current.—The unit of electrical current is called the ampere, which has been authoritatively fixed as the equivalent of the current strength, which can deposit .00033 grams of metallic copper, by the electro-plating process, in each second of time. In this respect it measures not only the current intensity, or available working energy, but also the rapidity of its exercise. The work above stated might readily be accomplished by a given current in ten seconds, instead of in one, but such a current would not have the value of one ampere, only of 1-10 ampere—since it required ten times as long to accomplish the result.

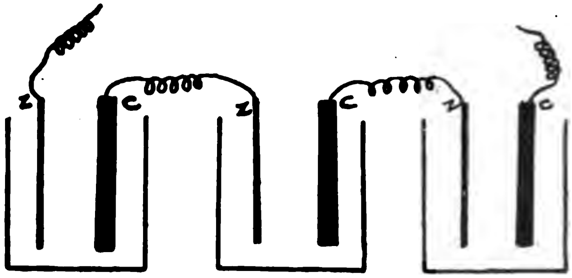


FIG. 326.—Diagram of a Series Circuit, showing Three Galvanic Cells in Battery. As shown, the copper, or positive, pole of the first cell is connected to the zinc, or negative pole of the second, and so on; leaving a negative terminal at one end and a positive at the other. Thus the current emerging from each cell passes through all those succeeding in line, the total voltage of the battery being equivalent to the sum of the individual voltages of the several cells. If, on the other hand, several motors, or other electrically affected apparatus, be connected in series, the result is to increase the "back pressure" (C. E. M. F.) on the same ratio, and hence cut down the operative efficiency of each.

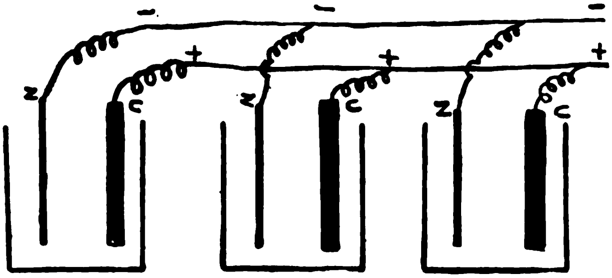


FIG. 327.—Diagram of a Multiple, or Parallel, Circuit, showing Three Galvanic Cells in Battery. In this system of forming the battery there are two main lead wires, one connected to the positive poles of all the cells, the other to the negative poles. Unlike the series system shown above, the effect is that the total voltage of the battery is equivalent to the voltage of one of the cells only, the pressure seemingly being cut down by this wiring. If, on the other hand, a number of motors, or other electrically affected apparatus, be connected in multiple, the "back pressure" (C. E. M. F.) is similarly decreased, enabling each one to give its highest operative efficiency.

Another frequently mentioned analogy for the ampere is the so-called miner's inch, which represents the product of an orifice one inch square, through which water is allowed to escape from a given tank or flume, by the height of the column of water in the tank, in inches. The miner's inch, is, therefore, in the first place, a measure of rate or velocity, giving inch-seconds, in fact, or the number of cubic inches of water passed in each second of time. Thus, while water flows at the rate of so many miner's inches, the electrical current flows at the rate of so many amperes; the rate per second, in both cases, being directly relative to the original pressure of energy at the source. Thus, it is inaccurate to speak of an ampere per second, since such an expression means simply a current of one ampere; thus also, in speaking of a current of ten amperes, for example, we do not refer to the amount of current passed in ten seconds, but to that passing in one second. There is, however, a unit of electrical measurement, which is called the coulomb, or ampere-second, which is the measure of electrical quantity, being equivalent to the product of the amperage of the current by the number of seconds it has been flowing.

The Volt, the Unit of Pressure.—Having determined the value of the resistance unit and current unit, it is a simple matter to determine the voltage produced by an electrical source. One volt E. M. F. can produce a current of one ampere on a circuit having a resistance of one ohm. There are several specified equivalents for estimating the exact value of one volt E. M. F., but these usually refer to the determined capacity of some given type of galvanic cell. It is sufficient to say, however, for ordinary purposes, the majority of commercial chemical cells are constructed to yield approximately one volt. The ordinary Daniell cell used in telegraphy has a capacity of 1.08 volt, and the common type of Leclanché cell gives about 1.50.

Ohm's Law of Electrical Circuit.—The value of the volt, as just given, which is to say, the amount of E. M. F. able to produce a current of one ampere through the resistance of one ohm, gives us a very good general statement of the fundamental principle of electrical science, which is popularly known as Ohm's Law. This is a law of proportions between the three factors in the production of electrical energy, by which any one of them, as well as the total power efficiency of the circuit, may be readily determined.

Ohm's Law may be specifically stated under six heads, as follows:

(1) The current is in direct proportion to the electromotive force, and in inverse proportion to the resistance.

(2) The current is equal to the electromotive force, divided by the resistance.

(3) The resistance varies directly with the electromotive force, and inversely with the current; hence,

(4) The resistance is equal to the electromotive force, divided by the current.

(5) The electromotive force varies directly with the current and with the resistance; hence,

(6) The electromotive force is equal to the current multiplied by the resistance.

As may be readily understood, however, all these various rules are merely so many different ways of stating the proposition involved in the first, which is, in fact, simply equivalent to that involved in the definition of the ohm already given.

The Watt, the Unit of Activity.—Having stated the law of proportions between the various component elements of a live circuit, we may readily see that the unit of active work performed by the current must stand in some determinable proportion to the other elements. Accordingly, we find that the unit of electrical activity, which is known as the watt, and which represents the rate of energy of one ampere of current under a pressure of one volt, is equivalent to the product of the voltage by the ampereage.

Other equivalents of the watt make it equal to the product of the resistance by the square of the current, or the quotient of the square of the voltage by the resistance. Thus, a current of ten amperes at a pressure of 2,000 volts will develop 20,000 watts, as will also another given current of 400 amperes at fifty volts.

The operative capacity of an electrical motor is usually stated in terms of watts, or kilowatts (1,000 watts), which may be reduced to horse-power equivalents by dividing by 746, which figure indicates the number of watts to an electrical horse power.

CHAPTER TWENTY-FIVE.

ELECTRICAL GAUGES—VOLTMETERS AND AMMETERS.

Electricity Meters.—The electrical gauges, ammeters and voltmeters, used on automobiles are constructed on the principle of the D'Arsonval galvanometer, with either a permanent or a variable field. With several of the more prominent manufacturers the former construction seems to be the one most approved. The general features are a small oscillating solenoid whose core is mounted on jeweled bearings, arranged like a dynamo armature between the poles of the permanent horseshoe magnet, with a hand or pointer pivoted at the bearing, so as to indicate the variation in electrical conditions on a graduated scale. A coiled steel spring attached at the base of the needle acts to restrain and control its movements, thus ensuring reliable indications of current strength or intensity.

Construction of the Volt-Ammeter.—The permanent magnets used on such instruments are of a special quality of hardened steel, magnetized to a point somewhat below the full magnetic capacity of the metal, and possessed of great permanence. The pole pieces of soft steel are firmly secured to the feet of the magnet, the joint being ground and intended to be permanent. The core of the coil is arranged to render uniform the field in which its coil oscillates, and over it are wound two layers of insulated wire—the first short-circuited on itself, for the purpose of "damping the movement of the coil by the generation of eddy currents within it, thus rendering the instrument a periodic, or dead-beat, in its indicatons." Above this short-circuited layer, and at right angles to its direction is wound the "active coil," consisting of a number of turns of fine copper wire, to which current is conveyed through the medium of the controlling springs at either end of the core spindle. The principal difference between the voltmeter and the ammeter is that in the former the active coil is in series with a resistance, and in the latter is connected across the terminals of a shunt block. The metal used in these resistance and shunts is an alloy having a temperature co-efficient of about .001 at 100° Centigrade. The voltmeter is, thus, really an ammeter; the resistance serving to keep the amperage in step with the voltage.

The Indicator Hand.—The pointer hand in such instruments is a rod of hardened aluminum wire, formed up with an eye for attachment to the axis of the core, and a counterpoise, shown in the diagrams, at the opposite end of the wire. The whole instrument is rigidly mounted on a cast brass bracket, which serves the double purpose of ensuring perfect rigidity and freedom from warping, etc., and enables the removal of the moving parts without disturbing the pole pieces.

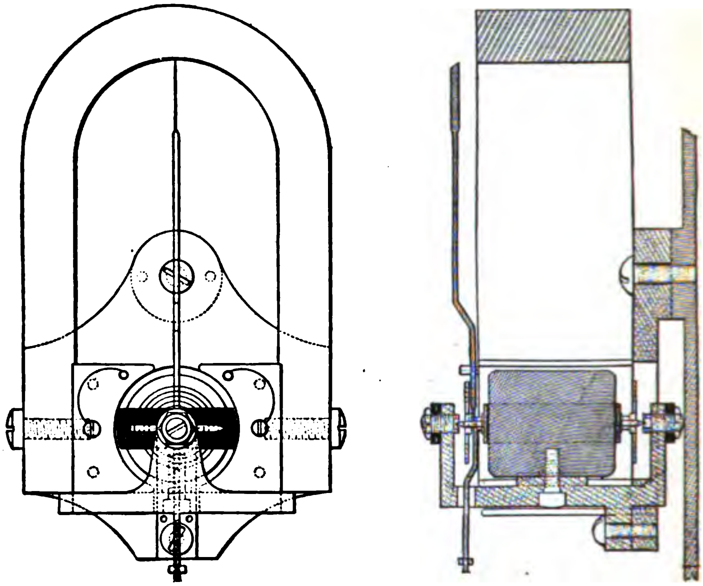


FIG. 328. FIG. 329.

FIGS. 328 and 329.—Sectional Diagrams Illustrating the Construction of Volt and Ammeters. The iron core is secured to the base plate by a screw. The active coil is shown wound around it from end to end.

Forms of Volt-Ammeter.—For automobile use a voltmeter and an ammeter are usually mounted on one base, with their graduated scale cards sufficiently near together to enable rapid reading of battery conditions. After slight practice the driver of an electric carriage can easily keep himself informed on the amount of current actually being used and on the probable duration of the charge. He can also learn to know the point of full charge, when his battery is connected to the generator. These instruments frequently have the scale traced on opalescent glass, so as to be illuminated at night by an incandescent lamp placed behind it. As shown by the accompanying cuts, the volt-ammeters made by different manufacturers vary in appearance—one type having the two scales arranged side by side, another, end to end. The voltmeter indicates the pressure between battery terminals, both in charging and discharging, while, in the ammeter scale, the space to the left indicates the amperage of the charging current, and that to the right, the amperage of the charging current are both in proportion to the discharge capacity of the battery, it is a simple matter to adjust the charging by the volt-ammeter readings, to suit the directions regarding the particular make of battery in use. As a general rule, storage batteries are constructed to give their highest discharge rate at the eight-hour discharge. Consequently, its capacity is rated at 40 ampere-hours, and the normal charging current is given as one-eighth of its ampere-hour rating, or as the equivalent of its

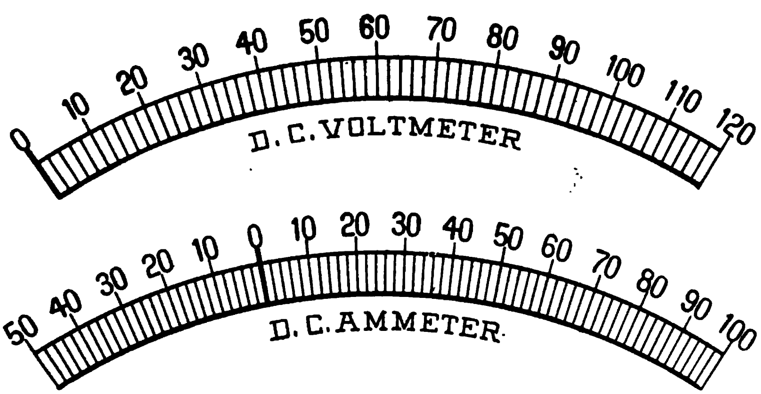


FIG. 330.—Index Scales of a Voltmeter and an Ammeter for Measuring the Pressure and Intensity on a Direct-current Electrical Circuit.

largest rate of discharge per hour. In this case, accordingly, the normal charging rate would be 5 amperes, and the current may be adjusted by the rheostat until the indicator hand points to 5 on the left-hand portion of the ammeter scale. If, however, the charging is to be done in shorter time than normal the amperage may be periodically adjusted to suit directions. The battery having a normal charged capacity of two volts per cell, is seldom charged above 2.6 volts, on the average, and never discharged below 1.75 volts per cell. Consequently, since the battery is always charged in series, the use of pressure is constantly indicated by the voltmeter needle, which registers the total voltage of the battery at all times in the charge. In discharging, it indicates the voltage of the couple in circuit, whether the battery unit be connected in multiple, series-multiple, or series; showing for a 4-unit 40-cell battery, 20, 40 and 80 volts, respectively.

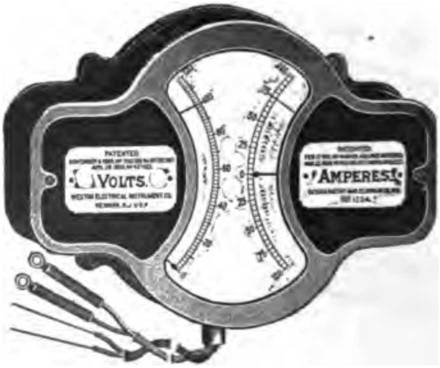


FIG. 331.—Weston Volt-ammeter of the Type used on Electric Vehicles. Other makes of these instruments have the index scales side by side, instead of end to end.

Reading Speed and Power Output.—In running the vehicle the voltmeter scale reading indicates the amount of charge still remaining in the battery—the difference between 1.75 and 2.6—and the ammeter rate at which it is being used. If the speed of a vehicle on a hard level road be determined and the reading noted in connection with it, the ammeter may be used as a very good speed indicator for operation under similar conditions.

The ammeter also indicates an overload, which, if above a definite specified figure, would likely damage the battery, as when attempting to start with brakes set, or in beginning the ascent of a heavy grade from a standstill. The amount of power being consumed by the motor is, of course, always the product of the volts by the amperes. Thus, with readings of 80 volts and 16 amperes, 1,280, or about 1.7 horse-power, are being constantly used.

Voltmeter Indications.—Although the voltmeter should always register between 1.75 and 2.6 per cell, the former figure indicating the point of discharge—it may happen that an unusually hard road will bring the needle temporarily below that point. Such indication does not of necessity mean that the battery is exhausted, as on coming upon a better road, it will quickly resume its normal reading.

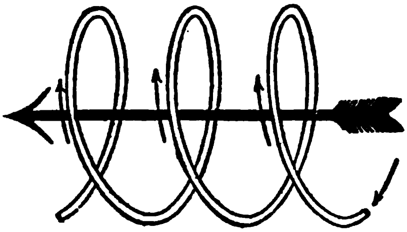


FIG. 332.—Diagram Illustrating the Directions of the Current in the Field Windings and the Induced Current, as found in magnets, solenoids and dynamo operation.

CHAPTER TWENTY-SIX.

THE CONSTRUCTION OF THE DYNAMO ELECTRICAL GENERATOR AND THE ELECTRICAL MOTOR.

Electrical Induction.—Electrical induction, as manifested in its simplest form, has been repeatedly demonstrated by two contiguous circuits of wire, the one containing an electric battery or other source of current, together with a switch for alternately opening and closing the circuit as desired; the other circuit of wire containing no battery or other source of current, but having its terminals connected to a galvanometer. If, now, we close the first circuit, allowing the current to flow from the electrical source, we will observe, as indicated by the galvanometer, that a current of somewhat less strength is flowing in the other circuit, in an opposite direction. This induced current, however, is only momentary, continuing only long enough to allow its strength and direction to be recorded. On opening the circuit, including the battery, thus cutting off the current, we again notice, as recorded by the galvanometer, that a current, weaker than the first one observed, is flowing in the second circuit in the same direction as that which has just been cut off in the first. This current is also momentary.

In regard to this phenomenon, several principles may be stated:

(1) Increasing the strength of the current in circuit 1 increases the strength of the momentary current in circuit 2.

(2) Decreasing or cutting off the current in circuit 1 decreases the strength of the current in circuit 2, also causing it to flow in the same direction as the current in circuit 1.

(3) If we move the current-carrying wire of circuit 1 nearer to the wire of circuit 2, we will find that a strong current is induced in circuit 2, which moves in a direction opposite to that in circuit 1. If we move the wire in circuit 1 further from the wire in circuit 2, we find that a weaker current is induced in circuit 2, moving in the same direction as that in circuit 1.

(4) If the wire used in circuit 1 is of low resistance and that used in circuit 2 is of high resistance, the current induced in cir-

cuit 2 will show a greater electromotive force than that flowing in circuit 1. Conversely, if the wire used in circuit 1 be of higher resistance than that used in circuit 2, the current induced in circuit 2 will show a lower electromotive force than that flowing in circuit 1.

The Production of Magnets.—The most familiar operation of current induction is seen in the production of an electro-magnet, which consists of a core of soft iron wound about with a certain length of insulated wire, preferably copper, on account of its high conductivity. As soon as a current is sent through the wire coiled about the iron core, its effects are seen in the fact that the core becomes magnetic, attracting iron and steel bodies, and in general exerting an observable effect upon any polarized conductor, such as a solenoid. As soon as the current in the insulated winding is cut off, the iron core loses its magnetic properties. If, however, a core of hardened steel be similarly wound with insulated wire, and a strong current be sent through it, the result will be that the steel will become a permanent magnet,

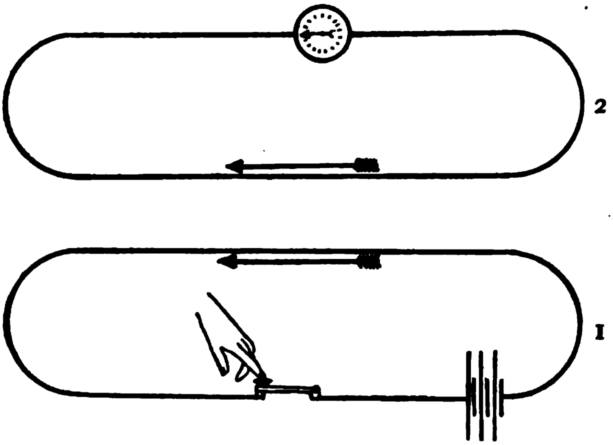


FIG. 333.—Diagram Illustrating the Action of Voltaic Induction Between Two Circuits: the one including a source of electrical energy and a switch; the other including a galvanometer, but having no cell or other electrical source. The direction of the battery current in circuit 1 is indicated by the arrow; the arrow in circuit 2 showing the direction of the induced current.

which is able to exert the characteristic magnetic effects for a practically indefinite period.

A bar of iron or steel thus temporarily or permanently magnetized invariably shows the phenomenon of polarity, manifested in the first place by the ability to attract the unlike poles and repel the like poles of another magnet, the poles being always determined as positive or negative by the points of the inlet or exit of the current, as in the case of solenoids. The magnet can also induce a momentary current in a closed circuit of wire in exactly the same fashion just described in connection with the ordinary action of current induction. These simple experiments demonstrate the fact that between the poles of any magnet there is a continual operation of force, the lines and activity of which may be shown by scattering iron filings on and between the two extremities. These iron filings, if allowed to adjust themselves, in obedience to the magnetic force exerted upon them, will be found to be thickest at the points nearest the extremities of the poles, and lightest at the points furthest from the extremities, in the latter positions describing arcs of circles, thus showing the strength and direction of the force acting upon them. Further, the intensity of the magnetic force is shown to be greatest when the two poles are connected by a piece of iron or steel, known as an armature, this being efficient in prolonging the magnetic activity of a permanent magnet, and preventing the dissipation of the magnetic force through a much longer period.

Electrical Dynamos and Motors.—The machines for converting mechanical movement into electrical current, and for converting electrical current into mechanical movement, in other words, the dynamo generator and the electric motor, respectively, are the same so far as the general features of their construction are concerned. In operation, however, the motor is the exact reverse of the dynamo. As just stated, the theory of electrical generation by mechanical means is that the lines of force of a magnet should be cut through, so that their strength and direction at any point or at any time should be made to vary constantly. In addition to this, it is necessary that there should be some means of collecting the current, resulting from the continual disturbance of the magnetic field, and supplying it to a circuit.

The Operative Principles of a Dynamo.—In order to review the principles involved in both the generation and mechanical utilization of the electrical current, it will be necessary briefly to enter into somewhat rudimentary principles. In an accompanying cut may be seen a diagram representing the simplest conceivable dynamo electric generator. As may be seen, the spindle, *A*, rotates between the two poles, *N* and *S*, of the magnet. Upon this spindle, *A*, is carried a loop of wire, the two terminals of which are connected to the two drums carried on the forward end of *A*. The metal of these drums, as indicated in the cut, is insulated from *A*, so that all the electric current generated by the machine may be taken up by the brushes, B^1, B^2. It is obvious that, when the spindle, *A*, is rotated in the direction of the arrow at the top of the cut, the double loop, *CC*, will cut through the lines of force, indicated by the dotted lines between *N* and *S*. Since, therefore, these lines of force have a more direct path between the two poles, when the loop, *CC*, is in a horizontal position than when it is in a vertical position, as shown in the cut, it follows that the momentary current induced in the circuit formed by brush, B^1, loop *C*, brush, B^2, and the outside circuit wire, *E*, connecting the two brushes, will constantly vary in strength, and also in direction of movement, as the two parts of the loop are moved towards and from the poles, *N* and *S*. Since the direction of the current must constantly fluctuate with the movement of the armature loops, *CC*, it follows that the current delivered to the outside circuit, *E*, through the two brushes, will be an alternating current, which is to say; one flowing first in one direction and then in another, the potential varying with the direction of flow. In order to make the current flow constantly in one direction, it is necessary to use a collector or commutator, the construction of which will be explained in place. Without this all dynamo currents would be alternating.

The armature of a practical dynamo or motor differs from the simple loop shown in the figure just mentioned, principally in the fact that a large number of such loops are mounted on a single rotating spindle, so that the magnetic lines of force are cut through a correspondingly larger number of times in a given period, with the result that the poles are shifted at a much higher frequency, and the alternations of the produced current are much more rapid.

The Essential Parts of Dynamos and Motors.—The essential parts of a dynamo generator and also of an electric motor are:

(1) The field magnets constructed like ordinary electro-magnets, and having two or any even number of opposed poles with their windings connected in series.

(2) The armature rotating between the fields, so as to cut the lines of magnetic force.

(3) The pole pieces, which are the exposed ends of the magnet cores.

(4) The commutator or collector.

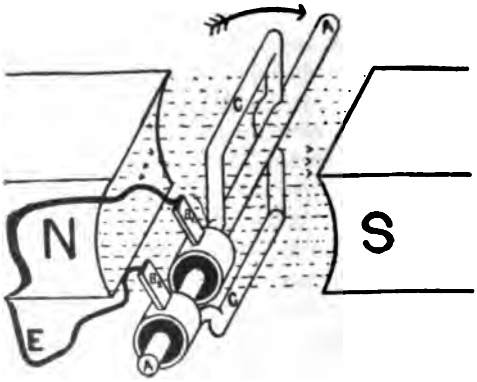


FIG. 334. -Diagram of a Dynamo Electrical Generator, arranged for producing an alternating current, showing the constructional and operative features. Here N and S are the positive and negative poles of the field magnets, between which the lines of force are shown by the dotted lines. A is the armature spindle; B^1 and B^2, the brushes bearing on the ring drums; C, the coil, or winding, of the armature; E, the outside circuit to which the current is supplied.

(5) The brushes which rest upon the cylindrical surfaces of the commutator, and as the terminals of the outside circuit, take up and deliver the current generated in the coils of the armature.

The Varieties of Dynamo-Generators.—There are a number of species of dynamo, discriminated according to the use for which they are intended, the arrangement of the armatures, the winding of the field magnets, and the kind of current they are intended to produce. For general purposes, however, we may discriminate three familiar forms of dynamo, according to the system adopted in the winding of the field magnets; these are:

(1) Series-wound dynamos, in which the two poles of the mag-

net are wound with a few turns of a heavy low resistance wire, one terminal of which is connected to one of the brushes, moving thence entirely around both pole cores, thence to the outside line and back through the other brush.

(2) Shunt-wound dynamos are wound in the same fashion as the series-wound, with the exception that the pole cores are wound with a large number of turns of high resistance wire, the field windings, however, forming a shunt-circuit from the main outside circuit, which has its terminals at the two brushes bearing on the armature. The terminals of the field magnets are also connected to the brushes.

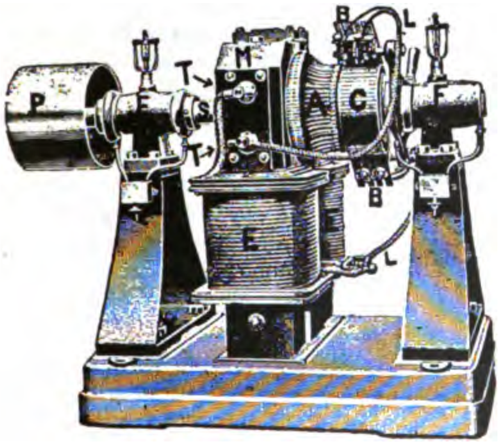


Fig. 335.—A Typical Dynamo-Electrical Generator, with parts lettered. A, the armature; B, B, the brushes; C, the commutator; E, E, the windings of the field magnets; M, the pole piece of the salient field magnet; F, F, bearings of the armature spindle; L, L, the lead wires; P, the pulley; T, T, terminal connections of the outside circuit.

(3) Compound-wound dynamos combine the features of both the series and shunt-wound machines, having the field magnets double-wound with (a) a few turns of heavy low resistance insulated wire connected to circuit as in the series-wound dynamos, and (b) a second winding arranged precisely as in a shunt-wound dynamo.

Shunted Field Windings, Their Use.—The object of using a shunted circuit for the windings of field magnets is that the machine may more readily excite its own fields at starting, and that the current may be produced before the rotating armature has fully taken up its speed. Some dynamos have their fields excited by a separate source of electrical energy, in which case the magnet windings are not connected to the brushes' ends, on the armature, but direct to the terminals of the outside source of electrical energy. As a usual thing, however, it is unnecessary to use a separate source of current, for exciting the magnetic fields, since there is a sufficient amount of residual magnetism, acting between the poles of the magnets, to start the generation of electrical energy, as soon as the armature begins to rotate.

Residual Magnetism and Current Generation.—This residual magnetism, which is a familiar property of an electro-magnet, that has once been magnetized, of course, has very weak lines of force at the beginning of the rotation, but these weak lines, being cut through by the coils of the armature, are able to produce a small amount of E. M. F., which sends a minute current through the windings of the field magnets, in consequence of which both the E. M. F. and the field currents are constantly increased until the rotation of the armature has reached its maximum speed. At this point, also, the output of the electrical energy has attained its highest point.

Construction of a Practical Armature.—The armature of a dynamo or motor consists of a drum or ring forming a core and support, upon which a number of coils of insulated copper wire are wound in the same general fashion as has been shown in connection with the ideal simple dynamo already mentioned. The drum or ring forming the supporting core is attached to the rotating spindle by a spider or key. The latter attachment is universally used with drum armatures. The most usual method of constructing armature cores for dynamos is to build them up by placing together, face to face, a number of thin discs of soft sheet iron, which are insulated one from the other by suitable varnish or enamel. The circumference of each of these discs is toothed or serrated, so that when a number of them are placed together the cylindrical armature body has a corresponding number of deep grooves running in its length. Into these grooves the insulated wire of the winding is inserted. The greater the number of the teeth in the circumference of the armature drum, the smaller the danger involved in the production of eddy currents, which are a troublesome source of overheating and other derangements of the machine. It is essential that the cores of the rotating armature should be composed of the softest iron in order that the greatest magnetic permeability may be obtained, since the body of the armature forms an integral part of the circulation.

The Commutator and Its Use.—The commutator of the dynamo or motor is one of the most essential elements in the generation and use of the current. Its function is to collect the current produced by the cutting of the lines of magnetic force, so as to cause them all to concur to a desired result, transforming what would naturally be an alternating current into a direct current. As usually constructed, the commutator consists of a number of L-shaped metal pieces, which are so formed that when one arm of each piece is connected to the insulating disc at the end of the armature drum, the other arm will constitute one segment of the cylinder arranged around the armature spindle. In general, the commutator is formed of alternating sections of conducting and non-conducting material, running lengthwise to the axis, upon which it turns. Each segment, as we have already seen, constitutes the point of connection between two sections of the armature winding; it is thus possible to collect the currents induced in the winding at the desired point, for although the effect of the magnetic induction upon the windings of the armature naturally tend to produce an alternating current, as already suggested, there are, as will be subsequently explained, certain points in the rotation of the armature at which the induced currents invariably move in one direction, owing to the permanence of the magnetic conditions at those points. These points are known as the neutral points, or points of commutation, and in order that the direction of the current sent over the outside circuit may be perfectly constant, the brushes which form the terminals of that circuit are here placed upon the commutator. In other words, the brushes are so arranged that they will bear upon the conducting segment of the commutator at exactly the neutral point in the rotation of the armature. These neutral lines are situated at either extremity of its determined diameter of commutation, which diameter is theoretically at right angles to the direction of the magnetic lines of force, as estimated for a two-pole magnet, and would be in that position practically but for the magnetic lag, which slightly varies the angle. The number of segmental bars on the cylindrical end of the commutator is naturally dependent upon the scheme of winding adopted on the armature, and the number of sections into which it is grouped. In general, an increase in the number of segmental bars diminishes the tendency to spark and lessens the fluctuations of the current. The increase in the number of bars, however, has fixed limits for several reasons. In the first place, principally in large machines, a great increase in the number of bars has a tendency to increase the voltage of the dynamo beyond the safe limit. In smaller dynamos, trouble speedily arises from the fact that each bar becomes so thin that a brush of proper thickness to collect the current would lap or bridge over more than two of them at once.

FIG. 336.—"Columbia" Electric Runabout. This carriage, weighing about 1,900 pounds, has a traveling radius of about forty miles per full charge of battery, and a maximum speed of thirteen miles per hour.

CHAPTER TWENTY-SEVEN.

THE OPERATION OF ELECTRICAL GENERATORS AND MOTORS.

Conditions of Dynamo Operation.—The dynamo electrical generator is a very sensitive and delicately organized machine, demanding for its efficient operation perfect adjustment of its various parts and a constant watchfulness for any symptoms of dynamo disease, overheating or sparking, or any of the results usually following imperfect adjustment or careless handling. These conditions, however, need not be enlarged upon here, since we are concerned only with the essentials of construction alike to the dynamos and motors, and with the general principles upon which the generation and use of the electrical current depend.

As already stated, the operation of a self-excited dynamo is largely indicative of the principles upon which it operates: The cutting of the lines of the residual magnetism between the cores of the field magnets, the production of induced currents in the coils of the armature, and their transmission through the circuit of the field magnet windings, where they are efficient in increasing the magnetism of the cores, also the E. M. F. output of the machine, as the rotation of the armature approaches the maximum speed.

The Polarization of the Armature.—The usual rule applying to the efficient operation of a dynamo is that the E. M. F. produced is in proportion to the number of turns of wire wound about the armature, and within definite limits also to the speed of its rotation. The result of the rotation of the dynamo armature is to produce a number of reactions between its windings and the magnetic field, with the result that the armature itself becomes a magnet, being constantly polarized at certain definite points in its path of rotation. According to the accepted rule of magnetic induction, the tendency is to produce poles in the armature at right angles to the lines of force, but since the neutral points, theoretically situated on the same diameter, are points of contact between the brushes and the commutator, where the current leaves and re-enters the winding of the armature, it will be found that the armature is really transformed into two separate adjacent magnets, having two north and two south poles, on either side of the diameter of commutation. These double poles, practically operating as a single pole, at the two extremities of the given diameter, act to produce the great distortion of the lines of magnetic force, which follow the rotation of the armature. As shown in an accompanying diagram, these lines of force are twisted into an oblique direction. This result is largely due to the fact that the polarity of the armature is not symmetrical with that of the field magnets. Were the brushes placed at any other point than the extremities of the diameter of commutation, the result would be short-circuiting of the armature coil. This distortion of the magnetic field, which is an important agent in the production of the current, must be regarded as the resultant of the two induced polarities of the armature, one of which is due to induction from the field; the other to induction from its own windings. It marks the fact that, in the process of shifting the neutral points as the armature rotates, the induced polarities are continued, with decreasing effect to be sure, hence continuing to exert an attractive or repelling reaction upon the field magnets.

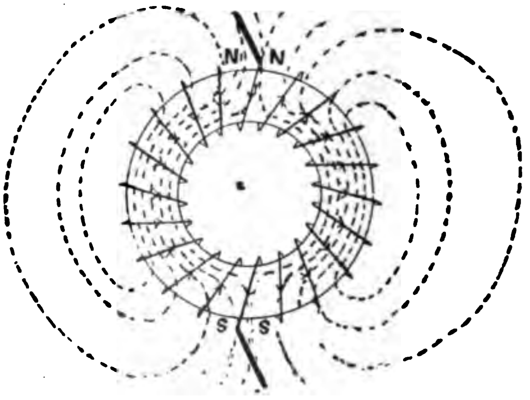


FIG. 337.—Diagram of the Polarization of a Rotating Dynamo Armature of the Ring Type, showing directions of the lines of force and of the induced current.

As shown in an accompanying figure showing the polarization of the rotating armature, it will be seen that the current produced in the armature windings are moving in two different directions between the contacts of the brushes. Entering at the north poles of the armature, their direction is through the windings, down either side to their exit at the south poles. These two oppositely moving currents, flowing between the north and south poles of the armature, which is to say between the negative and positive brushes, respectively, act upon the body of the armature after the manner of a current flowing in the windings of an electro-magnet, or through the helical portion of a solenoid. The result is that an induced current is set up in the armature itself, which, according to the rule above-mentioned, moves at right angles to the direction of the inducing current in the windings.

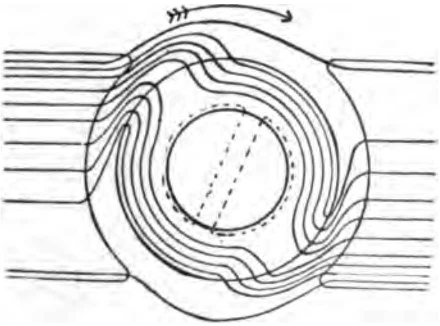


FIG. 338.—Diagram of the Distortion of the Lines of Magnetic Force as they pass through the Body of a Rotating Dynamo Armature.

Principles of Electrical Motor Operation.—The foregoing discussion of the dynamo electrical generator is included in this work, in order to prepare the reader for a better understanding of the electrical motor, for, as already stated, the electrical motor is the exact opposite of the dynamo in all matters touching its practical operation. This means that a typical dynamo may be run as a motor, with no other alterations than changing the position of the brushes to the negative lead.

The respective action of a motor and a dynamo may be understood from an accompanying diagram. It shows a dynamo and a motor coupled together, so that the current generated in the former is driving the latter. As will be seen, both the dynamo and the motor are rotating right-handedly, thus generating an electromotive force, tending upward from the lower brush to the higher, each upper brush, in this case, being the positive terminal of the circuit. The cut also shows that the brushes of the dynamo are advanced in the direction of the rotation, while the brushes of the motor are advanced backward in the opposite direction. The result of this variation in the arrangement of the brushes is. as is also indicated, the electromotive force in the dynamo, from which current is given forth, is in the same direction as the current, both moving from the lower to the upper brush, up either side of the armature. In the motor, however, where work is being done, and energy is leaving the circuit, the electromotive force is in a direction opposite to the current; the former moving from the lower to the upper brush, the latter from the higher to the lower brush, as indicated in the cut by the arrows. This brings us to the most essential practical difference between the theories on which the operation of dynamos and motors depend.

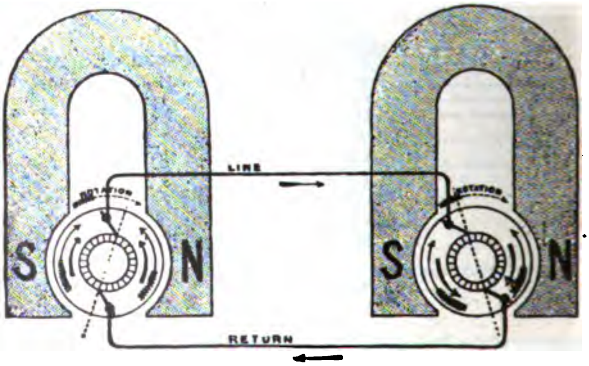


Fig. 339.—Diagram Showing the Operative Conditions of a Dynamo Generator and Electrical Motor. The machine on the left is the dynamo, that on the right the motor.

Comparison of Dynamos and Motors.—As already explained in connection with the dynamo, the rotation of the armature cutting the lines of residual magnetism constantly tend to increase the electromotive force of the current conducted to the coils and the field magnets, with the result that the E. M. F. of the current generated is constantly augmented, as the induced magnetic lines increase in number of strength until the maximum is attained.

With the motor, however, the current fed to the circuit is imparted partly to the windings of the armature and partly to the windings of the pole magnets, with the result that, both assuming polarity, the magnetic action tends constantly to attract the opposite poles of the armature, thus imparting a rotative movement. Thus the magnetic drag, which in the dynamo acts in the direction opposing rotation, and is, in fact, the reaction against the driving force, is in the case of the motor the real driving force, which propels the revolving armature, representing the pulling influence which the magnetic field exerts upon the armature wires, through which the line current is flowing, and also upon the protruding metal portions of the armature core.

FIG. 340.—Heavy truck of the Vehicle Equipment Co. Carrying capacity, 4 tons; speed, 6 miles per hour; travel radius on one charge of battery, 25 miles.

This operation is in accordance with the law relating to a current-carrying wire, situated in a magnetic field, in accordance with which it experiences a side-thrust, as it is called, which tends to move it forcibly in a direction parallel to itself, across the direction of the lines of magnetic force. This fact is well illustrated in Fig. 332, on page 435, in which the large arrow is represented as moving through the coil of wire, carrying current. The direction of the current in the wire is indicated by the small arrows, and the side-thrust, or magnetic push, by the large arrow.

Action of the Field Magnets of a Motor.—The second point to be considered in the practical operation of an electrical motor is that, while the magnetic action of the field tends to produce a rotation in the armature, the same rotation, necessitating that the armature windings cut through the magnetic lines of force, tends to the production of a counter electromotive force (C. E. M. F.), which, as previously mentioned, moves in a direction contrary to the direction of the current. As may be readily understood, the more rapidly the armature rotates, the greater will be this C. E. M. F., on account of the fact that a stronger field is necessary for the increase of speed, and, consequently, that a greater number of magnetic lines are produced, which the armature must cut through.

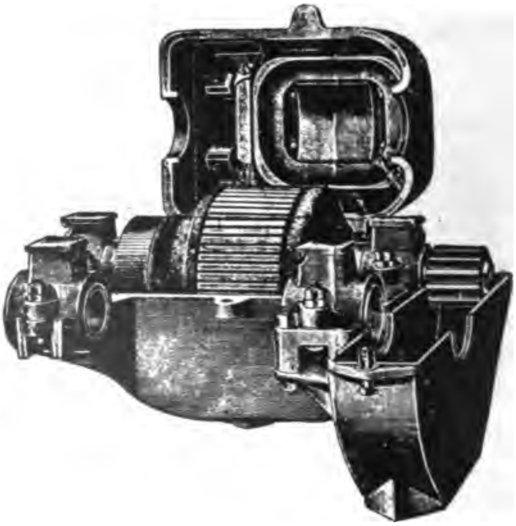


FIG. 341.—A Heavy Vehicle or Street-Car Motor, with single reduction, showing working parts in position.

Two facts, however, follow from this condition:

(1) As the armature revolves more rapidly, there is a diminished resistance to its motion, and on account of the increase of C. E. M. F. less energy is absorbed.

(2) When the motor is working under load, the armature necessarily revolves more slowly, with a consequent fall in the generation of C. E. M. F., and a greater absorption of energy.

The Speed and Torque of a Motor.—As may be understood from what has just been said, the increase of speed marks an increase of power in an electrical motor, just as in a steam or gasoline engine. There is, however, another consideration relating to the power of a motor, and that is the drag or rotative energy brought to bear upon the circumference of the pulley or spur attached to the end of the armature shaft. This electro-dynamic force, which tends to produce rotation of the shaft, is known as the torque, which is to say, the twisting power of the motor.

In estimating the efficient power of a motor, we have, therefore, to consider three elements:

(1) The power measured in pounds weight, which originally causes the rotation of the armature spindle, and which may be readily determined by experimenting with pulleys of various sizes, showing the power to raise various weights, or by a form of Prony brake, somewhat of the same description as is used for determining the efficient power of a steam or gasoline engine, as has been already described.

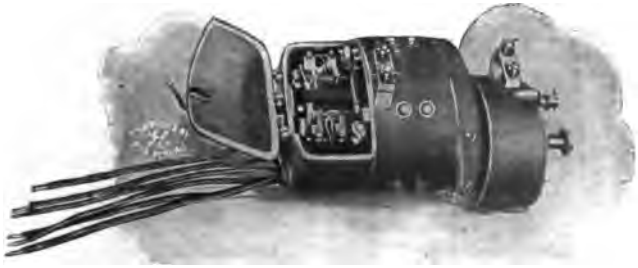


FIG. 342.—Type of General Electric Light Vehicle Motor, with case open, showing commutator and brush apparatus. The pinion end head is arranged for double reduction. Both end heads and gear housing are made of aluminum. Suspension by lugs to body. Capacity, 31½ amperes at 39 volts; 1,800 R. P. M. at full load.

(2) A second element entering into the determination of the efficient power of a motor is the diameter of the pulley.

(3) The number of revolutions per minute attained.

Illustration of Torque.—The operation of the torque of a motor may be illustrated by an accompanying diagram, in which, as shown, a rope wound about the axis of a pulley, *P*, and having a weight, *W*, attached to it, is able to cause the rotation of a pulley through the force of gravity exerted on the weight, *W*. Now the efficiency may be determined by two considerations: (1) The number of pounds in the weight, *W*, and the diameter of the pulley, *P*. If, for example, the weight is fifty pounds, and the pulley is of the same diameter as the shaft around which the rope is wound, the weight, *W*, will exactly balance a weight equal to itself; if the pulley is twice the diameter of the shaft, the weight, *W*, will be balanced by a weight of twenty-five pounds, and so on indefinitely; the amount of weight necessary to balance weight, *W*, being always in inverse proportion to the difference in diameter between the shaft on which it is coiled and the pulley, to which is attached the rope carrying the counter-weight. This is in accordance with the law of levers, that the power exerted on the long arm of a lever can raise a weight as much greater than itself, as the long arm is longer than the short arm, to which the latter weight is attached. Consequently, if the torque at the shaft of a motor armature is equivalent to 100 pounds for that diameter, it can exert a power of only fifty pounds with a pulley of twice the diameter of the spindle, and of only twenty-five pounds with a pulley of four times the diameter of the spindle.

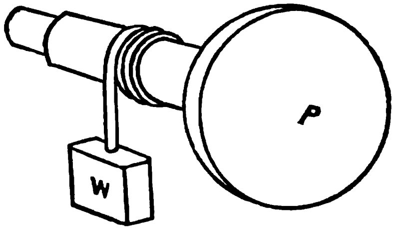


FIG. 343.—Diagram Illustrating the Theory of Torque.

This principle may be stated in another manner: that the pulley is capable of raising a weight which is in inverse ratio to the power exerted on the spindle of the armature, as the diameter of the pulley is greater than that of the spindle, because the work required of it is to raise its weight through a vertical distance equal to its own circumference. If, then, a pulley of 1 foot circumference can raise a weight of 1 pound to a vertical distance of 1 foot, a pulley of 4 feet circumference can raise only ¼ of a pound through a vertical distance of 4 feet.

Conditions of Motor Operation.—The torque of a motor armature—being stated in terms of pounds weight constantly acting to rotate the spindle—furnishes the first element in all formulæ for calculating the power of such a machine. It is evident, however, that while it represents the element of *length*, as found in the circumferential measure of the armature, and of *mass* or *weight* as found in the total resistance to be overcome in achieving a given result, as found in the load against which the spindle must revolve, the element of time must be supplied, in order to give an idea of the dynamic stress constantly at work. In other words, if the torque necessary to move a given load be estimated as 100 foot-pounds, the power of the motor depends solely upon the question of whether that 100 pounds is exerted in the unit time or whether it is a cumulative effect of a smaller energy acting through several units of time. Thus, 100 foot-pounds in torque might accomplish the raising of a given weight on a pulley of given diameter in one second, but 10 foot-pounds would require 10 seconds to complete the revolution. Knowing, therefore, that a given effect, as for example, keeping a certain machine in constant operation, demands an expenditure of 3,600 joules, the whole question of power-rating for the motor depends on whether this energy represents one watt-hour or ten 0.1 watt-hours.

Calculating the Power of a Motor.—In estimating the power of a direct current electrical motor in terms of foot-pounds, the fundamental formula gives the product of the torque, as found by brake tests, by the angular velocity. The angular velocity, whose unit is one radian per second, or such a speed as shall enable a given point on the circumference of the spindle to traverse an arc equal to its radius—(this is described on the unit angle of 57° 17′ 44.8″ +)—is found by multiplying the number of revolutions per second by twice the ratio between the circumference and diameter of a circle, which is 3.141592, usually represented by the Greek letter π (*p*). Thus:

Augular velocity=6.283184×r. p. s.

Then, with a motor showing a torque of 50 foot-pounds and with 50 revolutions per second of armature, the power in foot-pounds would be found by this formula:

Power=50×6.283184×50=15,707.96 foot-pounds.

Then: 15,707.96÷550=28.559 horse-power
or 15,707.96÷737.265=21.306 kilowatts.

Although the figures here given as to the rate of revolution for such a horse-power are somewhat in excess of actual practice, the end of illustrating the formulæ is sufficiently well attained.

Magnetic Units.—In estimating the power of a motor in terms of electro-magnetic quantities, or in designing a motor to give a certain power-effect, it is necessary to use a new set of units, to determine the special conditions involved. The principal electro-magnetic units are: of magneto-motive force (M. M. F.), the *gilbert;* of magnetic flux, or current, the *maxwell;* of magnetic resistance, the *oersted,* and of magnetic density, the gauss. These units are so calculated that the effect of the magnetizing electrical current may be accurately measured. Thus one gilbert is the total magnetizing force developed by a current of 0.7958 ampere flowing through one ampere turn of wire on the core of the magnet, while one ampere current passing through the same coil will produce 1.257 gilbert M. M. F. In calculating the number of ampere turns in a solenoid, it is necessary to multiply the number of complete convolutions by the amount of current carried. With a solenoid of 1,000 turns, adjusted to conduct a current of two amperes at a given pressure, we would have therefore: 1,000×2=2,000 ampere-turns. In obtaining the C. G. S. equivalent for the gilbert, it is evident that the formula, $4\pi \div 10$ $(12.5663 \div 10) = 1.257$, is used. Hence, to determine the magneto-motive force of the above magnetic circuit, we have 1.257× 2,000=2,514 gilberts. This M. M. F. in the magnetic circuit generates the magnetic flux under precisely similar condition to these under which the electrical current is produced. That is to say, it encounters a magnetic resistance, or the reluctance, which, in accord with Ohm's law for electrical circuit, varies directly with the M. M. F., and inversely with the flux. Thus:

$$\text{Flux} = \frac{\text{M. M. F.}}{\text{Reluctance.}}$$

Furthermore, just as electrical resistance increases with the length of the conductor and decreases as its area is increased, so magnetic reluctance, other properties being similar, is greatest in a core long in proportion to area, and least in a core whose area is the greatest per unit of length. The unit of reluctance is the oersted, which is equivalent to the amount of magnetic resistance offered by a cubic centimeter of vacuum. The reluctance of iron is represented by a fraction of this figure, although differing with the quality and variety, which determine the magnetic permeability of the core. It also increases as the magnetic flux reaches the point of retention of the core, which is estimated in gausses, or maxwells-per-cubic-centimeter, in order to indicate the degree of magnetic density. In this respect again a magnetic circuit is analogous to an electrical circuit, in which the effect of increasing the pressure beyond a certain safe point for a given size of wire—thus, of course, increasing the electrical current—is that the wire becomes overheated, the resistance is raised and dangerous consequences are liable to ensue. Thus, with a magnetic circuit also, the field-intensity increases with the rise of current in the coil, until the point of saturation is reached; after which the increase is on a much lower ratio.

In estimating the resistance of an electrical conductor, the operation usually followed is to find its diameter in terms of mils, or thousandths of an inch, and divide the square of this figure, or its area in circular mils, into the product of length by the unit resistance. The unit resistance is the number of ohms per mil-foot at zero centigrade, or the resistance of a wire 1-1,000th inch diameter and one foot in length. For copper wire this is 9.59 ohms. Hence, in order to find the resistance of 1,000 feet of No. 36 B. & S. (diameter 5 mils, area 25 circular mils) at zero centigrade we proceed as follows:

$$\text{Resistance} = \frac{1{,}000 \times 9.59}{25} = \frac{9{,}590}{25} = 383.6 \text{ ohms.}$$

In the same manner the usual formula for reluctance gives the quotient between the length of the solenoid in centimeters by the product of the area and the magnetic permeability, which latter quantity is the reciprocal of the reluctance. Since these quantities must be determined largely by experiment, or by reference to tables of magnetic conditions, it is more convenient to determine the reluctance from the flux found in terms of maxwells. However, in estimating for dynamos and motors, the reluctance of the air-gap, or clearance space between the armature and the poles, is an important factor.

In calculating the flux in the core of a magnet all formulæ whatsoever are based upon considerations that can be determined solely by experiment, among which are the number of ampere turns per unit of length, the magnetic induction, field intensity and permeability. The fundamental formula for determining the flux gives:

$$\varphi = \frac{4\pi NI}{L} \times A,$$

which is to say, the ratio between the quotient of 12.566368 and the number of ampere-turns by the length of the solenoid, multiplied by the cross-sectional area of the core. This formula, therefore, gives the product of the magnetizing force by the cross-section of the magnet. The magnetizing force is theoretically equivalent to the length of the pole, which may be determined as the quotient between the force exerted by the pole and the unit of polar strength. The unit of polar strength or field intensity is such a repelling force as is sufficient to act upon another unit pole of like polarity with the strength of one dyne, or fundamental C. G. S. unit. The pole-strength of a stronger, or of a weaker, magnet, is, therefore, equal to the quotient between its determined energy and the unit. The flux of a magnet is consequently to be found as the product of the pole-strength in dynes by the cross-sectional area, although in designing and accurately calculating motors and other types of magnetic machinery the formula previously given, including the number of ampere-turns, is necessary.

Power in Terms of Electrical and Magnetic Units.—In calculating the power efficiency of an electrical motor the effective flux may be experimentally determined in terms of watts (10^7 C. G. S.), as the force with which the field poles exert a rotative pull upon the armature. In this calculation the number of watts realized in work represents a given percentage of the watts delivered at the motor terminals, the difference between the two figures having been absorbed in internal resistance during operation. According to standard formulæ:

$$\text{Input watts} = \text{E. M. F.}\,\frac{\text{E. M. F.} - \text{C. E. M. F.}}{\text{Internal Resistance.}}$$

$$\text{Efficient watts}=\text{C. E. M. F.}\frac{\text{E. M. F.}-\text{C. E. M. F.}}{\text{Internal Resistance.}}$$

By solving these equations we find that the following ratios hold:

$$\frac{\text{Input watts}}{\text{Efficient watts}}=\frac{\text{E. M. F.}}{\text{C. E. M. F.}}$$

However, the efficiency of a motor in terms of watts-output depends upon the number of revolutions per second, since the stronger the flux the greater the speed. Thus, the efficiency in watts is determined by the following formula:

$$\text{Efficient watts}=2\ (3.141592) \times \text{r. p. s.} \times \text{T}\frac{746}{550}$$

in which is found the product of twice the ratio between the circumference and diameter of a circle by the revolutions per second, by the product of the torque (T) in foot-pounds at one foot radius of the armature and the ratio of watts to horsepower, reducing it to terms of 10^7 C. G. S. units.

While exact calculations for the design of a motor to give a certain power-effect involve the use of more complicated fomulæ, other authorities give readier average methods for determining the quantities involved in an active motor. Thus the reluctance per cubic unit of air clearance and iron core may be readily calculated for the M. M. F. generated by a solenoid of a given number of ampere-turns. To estimate the useful flux in an armature core several authorities give formulæ based upon the average magnetic density employed in motor armatures. According to average accepted figures the point of magnetic saturation of the core is about 16 kilogausses, and the average efficient flux about 10 kilogausses, or 10 maxwells-per-square-centimeter of cross-sectional area. To reduce to square inches, we multiply by 6.45, finding that the figure for magnetic saturation is about 103,200 gausses, and for average effective flux about 64,500. The average effective flux may be estimated, therefore, as the product of the cross-sectional area of the armature in square inches by the 64,500.

Knowing, then, the number of turns of wire, or complete convolutions on the motor armature; the safe current strength in amperes passing through the winding between the brushes, and the approximate useful flux, the torque of the motor in foot-pounds my be found by the following formula:

$$T = \frac{N \times I \times \varphi}{85{,}155{,}000} = \text{foot-pounds.}$$

Horse-Power of an Electric Motor.—In testing the horse-power capacity of a given motor at normal voltage, required factors of torque, speed and radius may be readily found—the first by brake test, the second by tachometer or speedcounter, and the third by simple rule measurement. These quantities having been determined, the horse-power may be found by the following formula:

$\text{H. P.} = \frac{T \times R \times S \times 2\pi}{33{,}000}$, in which *T* is the torque in foot-pounds; *R*, the radius of the armature; *S*, the speed in *revolutions per minute*; 2π the constant 6.283. The denominator represents the number of foot-pounds per minute making one horse-power.

CHAPTER TWENTY-EIGHT.

MOTORS FOR ELECTRIC VEHICLES.

Electrical Carriage Motors.—In several very essential particulars the motors used on electrical automobiles are masterpieces of the designer's art. The conditions under which they are used demand that they yield a high percentage of efficiency, in spite of their low power-rating; that they be capable of operating under several different pressures, and at as many different speeds; that they be independent of any such safety devices as fuse wires and cut-outs, and that they give good results at all loads.

Stationary motors are designed to operate at certain maximum figures for both load and pressure, and are provided with automatic protectors, which open the circuit so soon as the limit of safety in either particular is reached. The speed and power output may be regulated by adjustable resistances, so as to accommodate any requirement of load, and, since such variations are within a moderately limited range—always between points definitely predetermined—it is possible to arrange the windings to give the highest possible efficiency.

An automobile motor, on the other hand, must frequently operate at several hundred per cent. over load, as when propelling the vehicle up a steep incline or over a heavy road. Moreover, under such conditions, it is impossible that fuse wires and cutouts be used, since the point of overload is the very time at such full power is required. The unusual strain put on a motor on such occasions is not the only test of endurance and capacity, since it is frequently handled by a driver in such manner as to tax it severely; in starting from a standstill to ascend a heavy grade, to take an unusually rough road, or to begin travel with a heavy burden in freight or passengers, at the highest voltage.

In another respect an automobile motor must possess exceptional qualities—it must combine strength and lightness, so as to ensure good operation amid all the jolting and vibration of travel, with the fewest possible repairs. Its working parts, particularly the commutator and brushes, must be readily accessible, so as to be rapidly inspected and repaired, when necessary, and all electrical connections must be as firm and permanent as possible. In order to prevent crystallizing, short-circuiting and other injuries to the conductors flexible cables are always used between motors and batteries. The requirements as to the strength and firmness of construction appear particularly strenuous, when we consider that the vehicle must most frequently be driven by a person unskilled in the theory, management and repair of electrical machinery.

Among the first mechanical requirements in a vehicle motor are those that promote easy operation. Thus, all rotating parts move on ball-bearings, while the end of perfect lubrication is secured by wick cups or adjustable compression oilers. The entire mechanism is carefully enclosed in a tight case, in order to prevent abrasion from dust, grit, etc.

Since, as already stated, a vehicle motor is liable to be called on for sudden overloads at almost any time, its working parts must be carefully designed and adjusted to operate with the smallest possible percentage of such mishaps as are peculiar to electrical apparatus. Thus, it is necessary that the *insulation* used on all parts should be of a material capable of withstanding the high temperatures generated by work, without danger of burning-out. Suitable materials are found in asbestos and mica, both of which are largely used in up-to-date motor construction. For the same reason, good *ventilation* should be secured by even more thorough facilities than are used on any other variety of electrical machine. The *commutator* is another part requiring careful attention. It should not be so small as to spark and splutter on overloads, which is to say, its bars or segments should not be so numerous, in proportion to its size, as to involve sparking and overlapping with brushes of sufficient diameter to carry the required current.

This brings us to a consideration of the brushes, which must be of such material as to permit of firm adjustment, without grooving the commutator, and without offering too high a resistance to the current. In order to secure the ends of firm adjustment, without sparking or grooving, brushes composed of carbon, or some carbon combination are used on many automobile motors. Carbon is particularly suitable for this purpose, since it admits of permanent adjustment, thus preventing the many motor mishaps that come from poor brush arrangements. On the other hand, its resistance, according to many authorities, renders it unsuitable to permit of good work at the low voltages used on electric road vehicles. For this reason copper gauze brushes still have their advocates, who claim superiority, from the facts that lower resistance may be thus attained; also that, when properly constructed, they may be sufficiently well lubricated. Such brushes, when disposed radically on the surface of the commutator, can be firmly adjusted and offer sufficient resistance to give good commutation. In order, however, to avoid the disadvantages of both carbon and copper, and, to secure the good results to be found in either case, the practice of using a combination carbon and copper gauze brush is increasing among motor manufacturers and carriage builders. This latter may be said to be the really typical construction at the present time.

FIG. 344.—General Electric Motor, Designed for Heavy Vehicle Use, with single or double reduction. Capacity, 30 amperes at 85 volts; 800 R. P. M. at full load.

Summary of Vehicle Motor Requirements.—The General Electric Co., whose motors are widely used on American electric carriages, summarizes the requirements as follows:

"To attain the maximum possibilities in thoroughly efficient and reliable apparatus, the manufacturer must consider that combination which will give proper structural strength, added to the highest electrical efficiency. A properly designed motor for use in connection with storage batteries must possess a well-sustained efficiency curve at overloads, together with fine speed and torque characteristics. The amount of iron and copper used must not be stinted, for although generous proportions in this respect may add somewhat to the weight of the motor, this increase is more than counterbalanced by the resultant improvement in the torque, speed and efficiency characteristics obtained, besides decreasing the heating effect. It is obviously of small importance if a slight increment be added to the weight, if by so doing a motor is able to respond at once to extreme overloads without 'lying down' or unduly taxing the batteries, which at best are especially susceptible to injury by over-discharge. Again it is important that the speed and torque curves bear a proper relation to each other through all the range of the motor's load. This relation is a direct function of the efficiency of the machine and is only to be obtained by a judicious liberality in the use of high grade material.

"The mechanical characteristics of the General Electric Co.'s automobile motors have received very careful attention. The design have been carried out on the sturdy lines of the street railway motor, particular care having been exercised in providing generous bearings, rigid shafts, simple and durable brush fittings and commutator segments of such width and depth as to insure good commutation at all loads and long life of the parts. The frames of all General Electric automobile motors are made of cast steel, and the poles of laminated iron. Field and armature coils are machine-wound and thoroughly taped and waterproofed. The armature shafts are tapered and provided with a nut for securing the pinion."

Power Efficiency of Vehicle Motors.—The power range of the average automobile motor is remarkable. Thus, a motor rotated at three horse-power is usually wound to develop at least nine horse-power, or to take a 200 per cent. overload at the highest voltage. Few reliable authorities claim a higher capacity than this. However, as stated by one manufacturer, a motor for a 2,000-pound, two-passenger runabout, rated at 2½ horse-power, consumes 6,800 watts in ascending an 11 per cent. grade at 7 miles per hour, although no more than 360 watts are required to propel the carriage on an even asphalt roadway at 8½ miles per hour. These figures represent an effective power-range of between ½ horse-power and over 9 horse-power. There seems to be some uncertainty as to the precise power-rating of carriage motors, but, as matter of fact, they are wound to develop the highest constant power-output at the highest voltage (80 volts) used, with a high overload capacity for short spurts, as in hill-climbing, etc.

Operation of a Series Motor.—The motors used on electric carriages are generally series-wound, that type having been found very well adapted to most ordinary requirements, and from many points of view the most efficient in operation. It also possesses the valuable characteristics of automatically adjusting the consumption of power, as it were, to the load. Thus, at a light load it will take small current, while, as the resisting torque on the machine increases, power sufficient for demands is constantly absorbed, thus enabling the motor to take extreme overloads with high efficiency. It is wasteful, however, at very light loads, as in descending hills. Since, in a series motor, the total internal resistance is equal to the sum of the armature resistance and the field resistance, it follows that the current is the same under an

FIG. 345.

FIG. 346.

FIG. 345.—General Electric Siemens-Halske Type of Vehicle Motor. Four-pole, cylindrical, laminated fields. Capacity, 16 amperes at 80 volts; 1,000 R. P. M. under full load.

FIG. 346.—General Electric Motor for Medium-weight Vehicles. Capacity, 16 amperes at 85 volts; 850 R. P. M. at full load.

even load at any speed, and that the torque is in nearly direct proportion to the current. At a light load, with a small current, the rotative speed of the armature is comparatively great, and, owing to the generation of a high C. E. M. F., cuts down the current fed from the mains, in proportion to the difference between the impressed voltage and the internally generated voltage. Two things follow, therefore; that the efficiency is reduced at high speeds, and that it is reduced at light loads. With a heavy load, reducing the speed, the efficiency is correspondingly increased. Consequently, the most conspicuous problem before the practical motor-designer is how to produce a motor that will give a power-output proportionate to the weight of the motor, and, at the same time, rotate its armature at a comparatively low speed. This principle is amply demonstrated in the familiar fact that a motor, developing a low speed at a given power, is capable of being wound a higher voltage and can take large overloads, while one developing an unusually high speed per power unit it capable of small efficiency at any load. It may thus be seen that an increase of load, or resisting torque, acting to reduce the speed of armature rotation, will cut down the C. E. M. F., and, rendering a greater pressure available, will permit a greater current to flow in the windings, with the result of creating a greater flux, and, consequently, also, a greater power effect. This condition is explained by a simple application of Ohm's law. Thus, if the electrical resistance of a given armature winding be 1 ohm and the pressure between the mains is 20 volts, the current strength would normally be 20 amperes. Supposing, now, that the C. E. M. F. generated when running free be equal to 12 volts, the effective pressure will be represented by the difference between 20 and 12, or 8 volts, thus reducing the current to 8 amperes. As a general statement of the principle involved, it may be asserted that an increase in the resistance of the armature winding—by using a large number of fine wire turns—involves a large generation of C. E. M. F. for given rates of speed, and, consequently, a large drop in both pressure and speed under load. If, on the other hand, the armature resistance be small—the winding consisting of comparatively few turns of coarse wire—a given C. E. M. F. would involve a correspondingly higher speed for its generation, while a far larger proportionate current and torque would result with given decrease in the speed of rotation.

Fig. 347.—The Manner of Attaching Two-Carriage Motors, one for each wheel, with single reduction of speed. The motors are of the well-known "Lundell" octagon type.

Speed and Output of Power.—It seems evident that increase in pressure, involving high speeds at small loads, entails a corresponding loss of efficiency—judging this as the difference between the input and output in watts or kilowatts—thus enabling us to assert that the best efficiency of the motor and the greatest economy of current are both attained by using low pressure at light loads, and raising the pressure only with the increase of load. Such a rule is limited, of course, by considerations of the motor's construction, and the range of current strength to be obtained in its windings with definite variations of pressure. If, therefore, the armature of a given motor is wound with 1,000 complete convolutions of wire, representing, say, a resistance of 5 ohms, it will carry a current of 16 amperes at 80 volts, of 8 amperes at 40 volts, and of 4 amperes at 20 volts, giving for the three variations of pressure, 16,000, 8,000 and 4,000 ampere turns, respectively. The figure for flux will fall proportionately, giving a smaller power effect, and an efficiency-rating inversely proportionate to the speed of armature rotation.

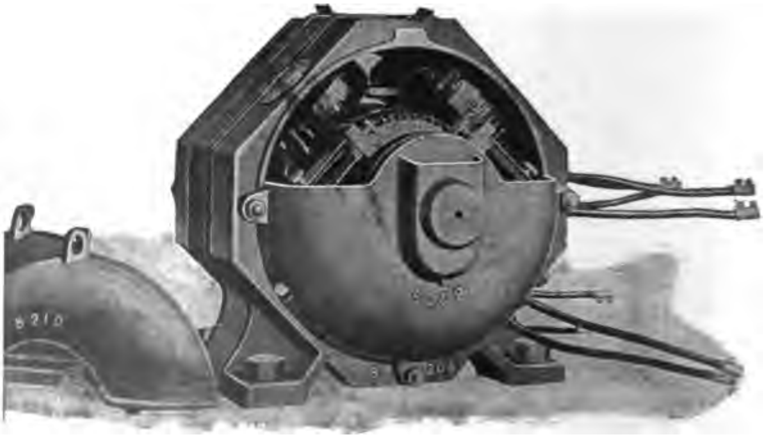


FIG. 348.—The "Lundell" Octagon Four-pole Motor, with case open, showing parts. Laminated field magnets and armature core. For vehicle use ranging between 2.5 and 15 horse power, wound for 80 volts. At this pressure the 2.5 horse power takes 28.5 amperes; the 5 horse power, 55 amperes; the 10 horse power, 110 ampers; the 15 horse power, 160 amperes.

Motors with Reducing Gear.—This practical situation has been recognized by a number of authorities, and several expedients have been proposed, in order to render possible a high efficiency and economy in vehicle motors. Thus, Farman, a French writer on the subject, says: "If the E. M. F. is varied by connecting up the accumulators in different ways, we shall obtain different speeds varying with the electromotive force. We may point out that, whatever the speed, the couple will remain constant for a certain intensity of current, as it is proportional to the product of the latter into the flux of force due to the exciting, so that for going up grades we shall not have a more powerful couple at our service than on the level, which is a great drawback. It would be better to let the motor revolve at a high speed and have a reducing gear, so as to utilize all available power, and yet travel at a slow pace.

FIG. 349.—"Herring-bone" Gear Transmission for Single Reduction used on the Waverley Electric Vehicles, viewed from the front. The small pinion is on the motor shaft, and the hub of the large gear forms the differential drum on the divided live rear axle.

"The method of varying the E. M. F. simplifies the transmission to a great extent, but it cannot be recommended, unless the car has only to travel over fairly level ground, when decrease in speed always corresponds to decrease in the power required."

Methods of Increasing Efficiency.—In spite of the very evident truth of many of the statements here made, the practice of varying speed and power by changing the couple of the battery has been retained by the majority of electric vehicle manufacturers, among whom there is a very definite tendency toward designs permitting of high power outputs at low speeds. This end is attained largely by accurately calculating the resistance of the armature winding to the pressures to be used, and, occasionally, by increasing the number of the field poles. A few manufacturers have strongly recommended the use of shunt or compound-wound motors, in order to maintain the armature speed practically constant for a given voltage under all loads.

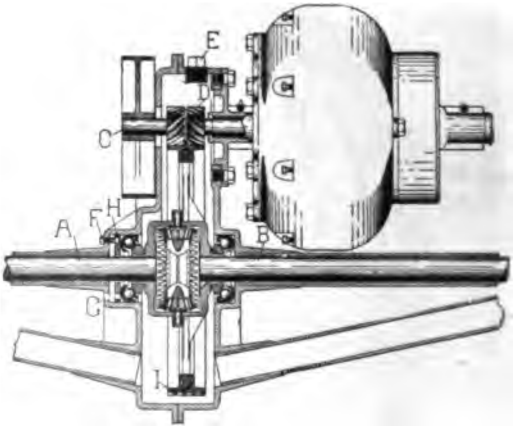


FIG. 350.—Plan Diagram of Single Motor Attached to Rear Axle Through "Herring-bone" Single Reducing Gears. A is the left-hand section of the divided rear axle; B, the right-hand section of the rear axle; C, the brake drum; D, the spiral pinion on the motor shaft driving the worm gear, I, on the differential; E, plug for greasing gears; F, set screw for locking ball race; G, slot for wrench to adjust threaded ring, H, against ball bearings.

Motor Development in America.—In desiging or estimating the efficiency of an electric motor it must be always borne in mind that the lower the power rating the greater the speed of armature rotation. Thus, while a good ½ horse-power motor has a normal speed of 1,300 revolutions per minute at full load, or 2,600 revolutions per output of horse power. a 1 horse-power motor has a normal speed of only 1,000 revolutions per minute, under load a 5 horse-power motor, but 900 revolutions, or 180 revolutions per horse-power output; higher powered motors have even lower speeds. As can be readily understood, therefore, the lower the horse-power rating, and the higher the speed, the lower the efficiency. Thus, with the speed of rotation above mentioned, the average 1 horse-power motor has an efficiency of about 72 per cent.; a 6 horse-power motor, of about 81 per cent., and no motor of much over 90 per cent. In comparison with these figures, we may quote the published statements of several manufacturers of carriage motors, as showing the high state of perfection of motor-design at the present time in America. One manufacturer, the Elwell-Parker Co., producing three sizes of carriage motor, rated respectively, at ¾, 1½ and 2½ horse-power, claims a speed of 1,200 revolutions per minute, and a 79 per cent. efficiency, for the first; a speed of 1,050 revolutions, and 80 per cent. efficiency for the second; and 850 revolutions and 82.5 per cent. efficiency for the third. These machines weigh 83, 115 and 155 pounds, and measure complete with cases, respectively, 9⅝x12 7/10",

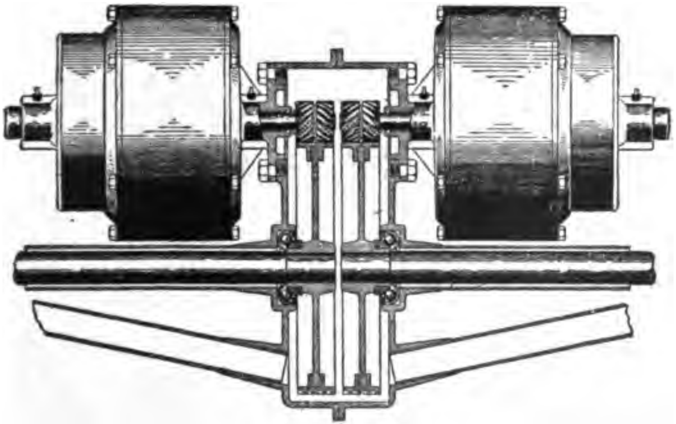


FIG. 351.—Plan Diagram of Two Motors Working on "Herring-bone" Gears to Two Sides of Divided Rear Axle Without Differential.

10 9/10x14½", 11½x17 6/16". The first figures in each instance are for diameters, the second, for length of case, not measuring the spindle at either end.

Shunt and Compound Motors.—With a view to increasing the efficiency of automobile motors, several designers have proposed the use of shunt and compound windings, whose advantages in several particulars have been made apparent in other branches of electrical activity.

[illegible]—Waverley Delivery Wagon, with double motor equipment, as [illegible] in Fig. [illegible]

Shunt-wound motors, in which the field coils, instead of being [illegible] series with the armature, are on a shunt between the lead [illegible] are very largely used on constant-potential circuits. [illegible] account of their ability to regulate the speed, maintaining it [illegible] uniform rate, in spite of the increase in load up to a [illegible] point. With differential-wound compound motors the [illegible] effect of speed regulation may be attained, on a constant-potential circuit, by the interaction of currents in a low-resistance winding in series with the armature and a high-resistance coil in shunt. The former coil as a demagnetizer, causing the motor to speed up under increased load, by weakening the field, which furnishes an offset to the tendency to slow down, under such conditions, always varying the magnetic strength inversely to the load. Of course, at very excessive overloads the danger is that the current in the series winding will completely neutralize that in the shunt, with the result of checking armature rotation, and often involving even greater disadvantages.

Regarding the use of shunt-wound motors in electric carriages, a well-known autombile authority writes as follows: "The use of shunt motors on street cars driven by storage batteries was early claimed as a great advantage. but most automobile motors are series-wound. This cannot continue, for the advantages of shunt motors are too manifest. What better method for braking is there than to drop the controller off a notch or two, and, with the motors acting as dynamos, turn the surplus energy back into the battery? The ammeter provided on most electrically-driven vehicles is a perfect guide in doing this. The instrument should be differential, and, as the needle comes back to zero, notch by notch may be turned off. In hill-climbing, one third and even more of the extra energy consumed can be recovered by coasting down the other side with the controller set a notch or two below the coasting speed. These well-known possibilities of shunt

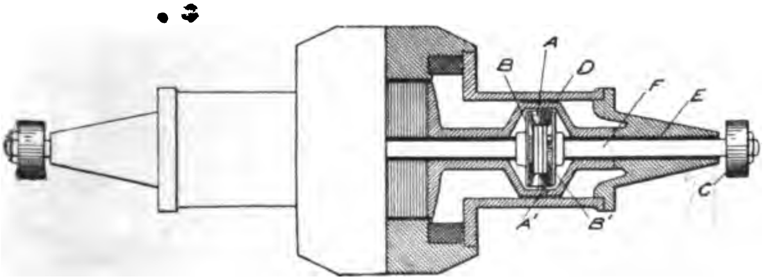


Fig. 353.—Part Sectional Diagram of a Single Motor, arranged for driving both wheels through differential gear. A and A′ are the pinions of the differential gear; B, the bevel gear of the left-hand road wheel; D, bevel gear on right-hand road wheel; C, spur pinions driving internal gear on road wheels; E, sleeve on rotating through shafts, F, of pinions, C and C.

motors could not be fully attained on street cars, but with automobiles the problem is very easy.

"Full field strength should be used at all times. The first act of the controller should be to make the field connections, and this condition need not interfere with the commutation of the cells. The field coils may be divided into as many sections as batteries. and each battery given a section. This arrangement will not interfere with the batteries being switched in any series or multiple combination that may be desired. In the annexed figure two motors are shown in diagram, each of which has two field coils. The battery is divided into four sections, a very common arrangement, and each section excites a field coil."

Such an arrangement as is here suggested, combined with a series field coil, has evidently been put into operation by one or two manufacturers. Of course, with uniformly-wound shunt and series coil, both fields are greatly excited at high load, and, the magneto-motive force of both acting in the same direction, the energizing flux would be somewhat increased, with consequent reduction of armature rotation, in developing the required C. E. M. F. Proper adjustment can largely neutralize the drop in speed that is liable to follow the drop of pressure in the armature resistance, thus enabling the maintenance of nearly constant speed under nearly all loads.

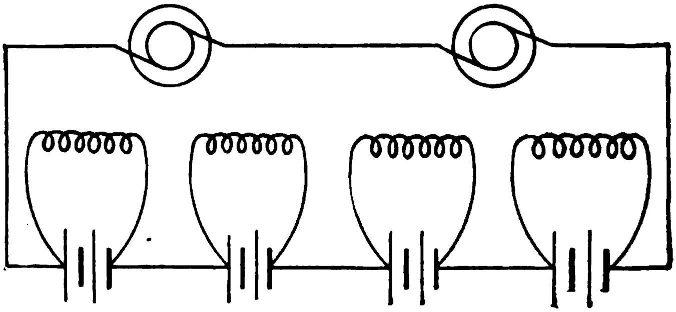


FIG. 354.—Diagram of Circuit Arrangements with Shunt Motors, as explained in text.

Operation of Compound Motors.—The manufacturers of a well-known make of American electric carriage using a compound-wound motor speak as follows of its operation: Defining the shunt winding as "an additional path for the electric current for the passage of the lines of force, giving more torque and less speed," they assert that, "to give greater impetus to the motor and accelerated speed to the vehicle, we weaken the field of the motor by cutting out the shunt by means of the shunt button on the floor of the carriage. This gives the maximum speed to the vehicle. The advantage of the compound-wound motor is at once apparent, as the cutting out of the shunt cannot weaken the field abnormally. Hence, the driver, if he chooses, may run at his maximum speed at will, without the least injury to the motor, but at the expense of distance, by reason of the more rapid discharge of current."

FIG. 355.—Studebaker Electric Runabout, with Chain and Sprocket Connections between Motor hung on the Body and the Rear Axle. The advantage is that the motor is protected from the jars of travel by the springs.

A "Recharging" Shunt Motor.—Another American carriage motor of the compound-wound variety is thus described: "It is a well-known fact that the efficiency of a series motor is very low until enough current flows through the field coils of the motor to produce considerable magnetic flux, and while a series machine can take extreme overloads with fair efficiency, it is apt to have a low efficiency on good smooth ground, because the work required of the motor is so small under the latter condition.

"The motor illustrated herewith, as well as its controller, is designed to overcome in a considerable degree the objections noted. It is compound-wound, and the controller is so arranged that the shunt field is constant whatever the voltage on the armature may be. The strength of the shunt field is the same, whether the motor is running with 20, 40 or 80 volts. This arrangement makes it possible to attain a very high efficiency at low

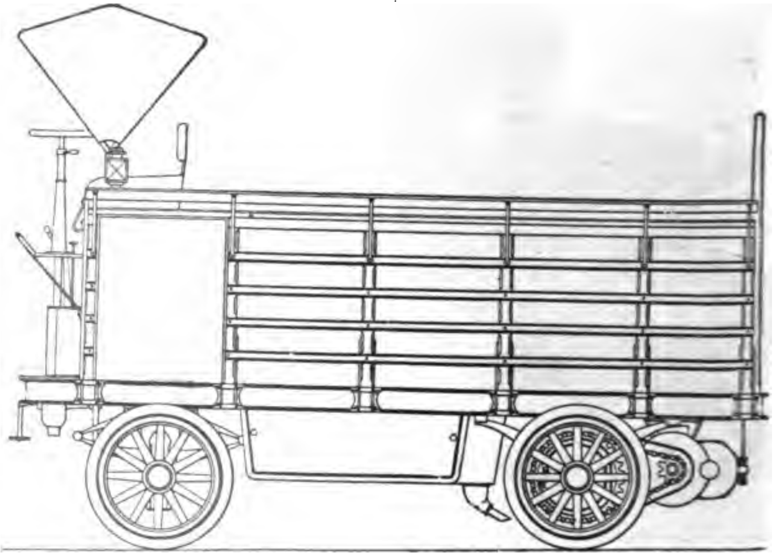


FIG. 356.—Chain and Sprocket Double Reduction for Heavy Trucks. As here shown, the motor is hung above the springs, missing the jars of travel.

loads, which is not possible with a series motor. Another very important advantage is the saving of most of the power which is usually wasted as friction in mechanical brakes.

"This motor drives a carriage carrying 40 cells of battery at about 4 miles an hour on the first speed, or about 20 volts at the brushes; the rate is 8 miles an hour on the second speed, with 40 volts at the brushes, and 16 miles an hour on the third speed, with 80 volts (the battery all in series) at the brushes. The advantages of the shunt winding may be best shown by taking a concrete example. Suppose this carriage is traveling at a rate of about 8 miles an hour and begins to descend a grade; the speed will be increased and the C. E. M. F. of the armature will increase. At a rate of about 9 miles an hour, no current will pass through the armature, and when the speed rises to about 9½ miles, the C. E. M. F. will have still further increased, so that the motor becomes a generator and charges the batteries. Any greater increase in the speed of the carriage is impossible, because a slight increase will very greatly increase the load on the motor by increasing the charging current.

"If it is desired to descend the hill at a lower rate of speed than between 9 and 10 miles an hour, the controller can be moved to the first speed, and it will be impossible for the carriage to descend at a higher rate of speed than 5 miles an hour; and the power which would have been wasted in the friction of the mechanical brakes in descending the hill will be used in driving the motor acting as a dynamo and charging the storage batteries. This is also valuable in bringing the carriage to a lower speed on level roads. If the carriage is traveling at the highest speed and the controller is moved to the second speed, the momentum of the carriage drives the motor as a dynamo and rapidly charges the battery until the speed drops to 8 or 9 miles an hour. When the speed decreases so that the batteries are no longer being charged, the controller can be placed at the first speed and a still further charge of the batteries be effected. This brings the speed to about 4½ miles an hour."

The manufacturers further enlarge on the merits of their "recharging motors" as follows:

"A still more important advantage over the ordinary series motor is that the average efficiency is higher—particularly at light loads. It is a well-known fact that a carriage driven by a series motor requires all of half and probably two-thirds of the current, when running down a 3 per cent. or 4 per cent. grade, as is required when running on a level. The efficiency of a series motor is very low below half load.

"When a carriage is running down a ½ per cent. grade, for example, the load is very much less than when running on a level, but the current required by a series motor is very little less than that required on a level. On the other hand, our motor takes current strictly in proportion to the load, and the saving in current consumption is very great.

FIG. 357.—Electric Brewery Wagon of the Vehicle Equipment Co. Carrying capacity, 5 tons; speed, 6 miles per hour at full load; travel radius on one charge, 25 miles.

"Due to the two causes mentioned, a carriage driven by this motor will travel from 15 to 40 per cent. further than the same one driven by an ordinary series motor. For instance, a carriage driven by a series motor, built by a well-known firm, required 13 amperes to drive it down a certain grade of about 4 per cent., while the same carriage equipped with one of our motors and controllers, descended the same grade and charged the battery

20 amperes. The change of the machine from motor to dynamo is entirely automatic. It is impossible for one sitting in the carriage to tell whether the battery is receiving current from or delivering current to the motor."

If the findings of such experiments hold good for general practice, the advantages of a recharging motor, as an economizer of current, must be evident on reflection. Of course, the recharging effected under ordinary conditions could scarcely add very much to the radius of travel. Could such a motor be driven as a dynamo from a separate source of power, it is probable that it could recharge the battery at slow rate, provided that the speed be sufficient. A motor of this type, having a field magnet diameter of 9½ inches and a total length between ends of bearings of 13 inches, gives 1½ H. P. at 1,500 revolutions; one of 11½x 14⅛ inches for same dimensions, gives 2½ H. P. at 1,200 revolutions, and one measuring 14x18½ inches, gives 5 H. P. at 900 revolutions.

CHAPTER TWENTY-NINE.

PRACTICAL POINTS ON MOTOR TROUBLES.

Electric Motor Troubles.—The following digest of common motor troubles is given by Mr. George T. Hauchett in *The Automobile,* and is re-printed by permission:

"While it is not necessary to be an electrician to operate an electrically driven vehicle, it is of great advantage to know what to do when certain troubles occur.

"Let us consider first a single motor equipment provided with a battery which is connected in different ways for the various speeds. Suppose an attempt is made to start, and the vehicle does not respond and the ammeter shows no indication. This almost invariably means open circuit; that is to say, the path for the electricity from the batteries to the motors is not closed. We may find open circuits at any of the following points:

"A. The battery contacts. They may be and often are so badly corroded as to prevent the necessary metal-to-metal contact.

"B. The controller. A connection may be loose or the fingers may not make contact.

"C. The running plug may sometimes be out or not making proper contact.

"D. The motor brushes. May have dropped out or the tension may be so weak that they do not make contact.

"E. The emergency switch may be open.

"Leave the controller till the last. It is but a moment to inspect the other joints and to discover the trouble in them after an hour's fussing with the controller is clearly a waste of time.

"If the carriage operates at any of the speeds and fails to operate on the others, the ammeter needle falling to zero, the trouble is almost certainly in the controller. The contact fingers that are brought in play at the inoperative speeds should be inspected. Often a screw adjustment or a rub with a piece of emery cloth will correct the difficulty.

"If the motor tries to start, but the current is not sufficient, as shown by the ammeter, poor contact or weak battery may be suspected. Discharged battery will be betrayed by a low voltmeter indication, but if the voltmeter registers the normal amount, poor contact should be sought. Any contacts which are part of the electric circuit, such as binding posts, brushes, switch jaws or controller fingers must be bright metal-to-metal contacts. If they are dirty or corroded the contact may be so bad that the flow of current is seriously reduced or interrupted altogether.

"**Improper Connections.**—Sometimes the absence of ampere indication and no motion of the vehicle points to a very serious trouble, namely, the improper connection of the batteries. This will be shown by heavy sparks at the controller; in fact, heavy sparks at the controller, absence of ammeter indications and refusal of the vehicle to move, could only be caused by one other difficulty than this, which will be discussed further on.

"When the battery is not properly connected, the motion of the controller causes the sections of battery to exchange current between themselves at a ruinous rate. The terminals of the cells and those to which they should be connected ought to be plainly marked, or, better still, so constructed that it is impossible to go wrong. If the trouble just cited is the fact, one or more sets of terminals of the cells will be found to be connected to the wrong wires.

"If the vehicle fails to move and the flow of current as indicated by the ammeter is enormous, shut off the power at once. Serious damage may ensue if this is not done. Then look to see if:

"A. The brakes are on.

"B. The vehicle is stalled or blocked.

"C. The gears are free and there is no obstacle between the teeth.

"If the motor makes a noticeable attempt to move the trouble is probably something of this mechanical nature.

"**Short Circuits.**—If, however, large current is indicated and the motor remains absolutely inert, the trouble is electrical, and the inference is that the current does not go through the motor at all. Lift one of the motor brushes and try the vehicle again. If the large current is still indicated, the inference becomes a certainty. This trouble is known as short circuit, that is to say, a spurious path for the current which deflects it out of the motor.

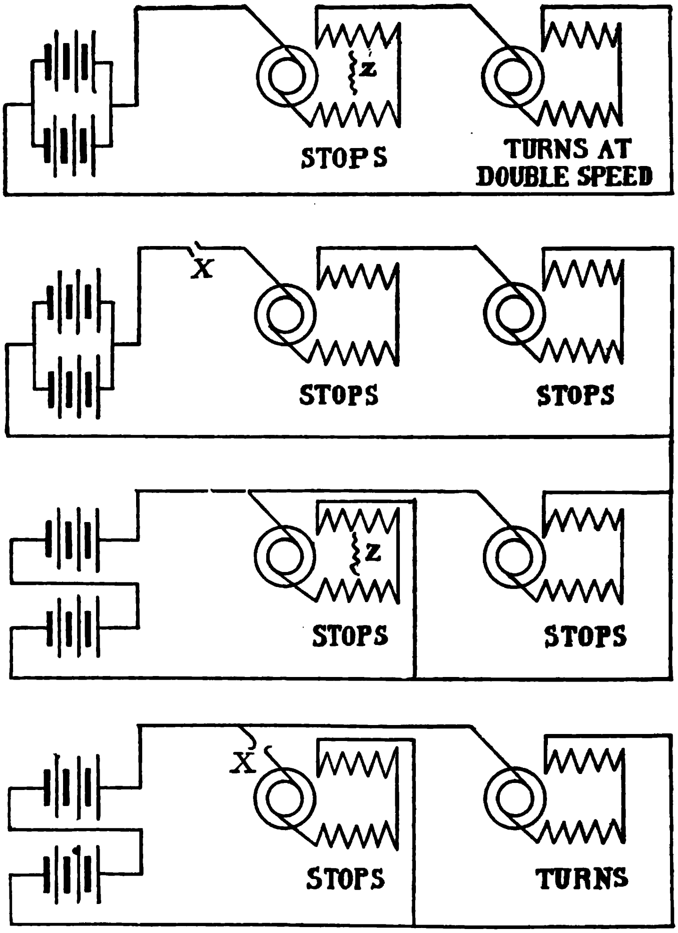


FIG. 358.—Diagram of Common Motor Troubles, as described in the text.

In the controller may be sought:

"A. Foreign pieces of metal making contact between portions of the electrical circuit.

"B. Loose fingers which may make contact with wrong parts of the controller or with each other.

"C. Dirt between the fingers or contacts.

"D. Breaks in the insulation permitting the wires to make contact with adjacent metal or with each other.

"If the controller appears to be all right, look in the motor for:

"A. Broken insulation, allowing the bare wires to touch the frame or each other.

"B. Dirt between contacts or between live metal and the motor frame.

"C. Foreign materials bridging contacts.

"In such a case it is sometimes of assistance to turn on the current for an instant. The defective place may betray its locality by a smoke or spark.

"If, when the brush is lifted, and the vehicle tried, the excessive current indication disappears, there are but two electrical troubles that are possible:

"A. The magnet coils of the motor may be short circuited.

"B. The ammeter may not be reading correctly.

"The latter trouble is least likely; the former should be sought first.

"A series motor with a short circuited magnet coil will call for a large current but will do nothing with it. Therefore, examine the magnet coil terminals for troubles of this nature.

"A short circuit may exist even if the ammeter does not indicate it. In such a case it is usually found in the controller, which sparks heavily when operated, although the vehicle does not move. This combination of phenomena also indicates improper connection of the batteries, as has been previously explained.

"An excessive call for current is accompanied with a drop in the voltmeter indication.

"**Two-Motor Troubles.**—With a two-motor equipment the difficulties that may arise differ but little. A few which are peculiar to this type may be mentioned. Such motors are sometimes run in two ways. The first notch connects the motors in series, while the higher speed notches connect the motors in parallel. If one of the motors open-circuits on a series notch, the vehicle stops, for the entire motive circuit is broken. If it open-circuits on a parallel notch, that motor stops and the other, with its circuit to the batteries intact, continues to run and may cause the vehicle to make some abrupt and unexpected turns. If either of the motors gets short-circuited, the exact converse takes place. If the accident occurs on a series notch the unimpaired motor continues to run, and, it may be added, at nearly double its previous speed. If it occurs on a parallel notch a short circuit on one motor constitutes a short circuit on the other also, and if the short circuit is sufficiently severe both motors will stop, even though an enormous current may be drawn from the batteries."

CHAPTER THIRTY.

METHODS OF CIRCUIT-CHANGING IN ELECTRICAL MOTOR VEHICLES, AND THEIR OPERATION.

Varying the Speed and Power Output of a Motor.—The methods employed to vary the speed and power output of an electric vehicle motor consist briefly in such variation of the electric circuits as will modify the pressure of the batteries on the one hand and the operative efficiency of the motors on the other. This is a very simple matter and may be expressed in a few words. As is well known, there are two general methods of connecting up both electric batteries of any description and electric motors. They are the series-wiring and the multiple-wiring, or parallel-wiring. In series-wiring, various cells of a galvanic battery, or the several units of a battery of dynamos, are connected in line. At one terminal of each is the negative pole, at the other the positive—each unit in combination having its negative pole connected to the positive pole of the one next following. In the parallel method of wiring the various units are each separately connected at their positive and negative poles to two lead wires, one of which is the positive pole of the battery, the other the negative.

Effects Obtained by Varying the Circuits.—Electric motors, lights and other electrically effected devices are similarly connected in circuits, either in series or parallel. Now, in the matter of circuit arrangements on this plan, one general principle may be laid down, which is that a connection of a number of electrical generators in series involves an increase in the power pressure of the battery, which is equal to the sum of the individual voltages. Connecting a number of generating units in parallel or multiple has the effect of producing a pressure only equal to the voltage of one of the units. Thus, if four generators of 10 volts each be connected in series, the pressure is equal to 40 volts. If, however, they be connected in parallel or multiple, the pressure is equivalent to but 10 volts, the effect in the latter case being the same as if but one unit were in circuit, so far as the voltage is concerned. On the other hand, where four motors are connected in series the efficient pressure of the circuit is reduced to very nearly ¼ for each motor, the C. E. M. F., generated by their operation, serving to cut down the average of efficiency; but when four motors are connected in parallel, which is to say, bridged between the limbs of the circuit, the greatest available pressure of the battery is able to act upon each one of them.

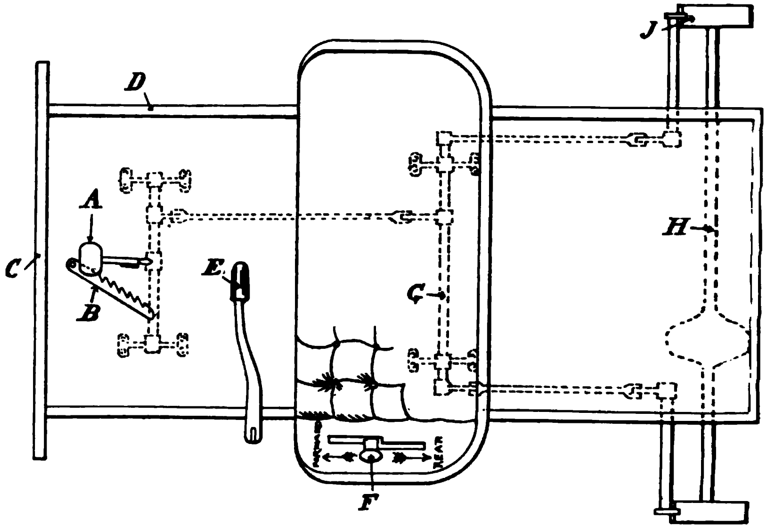


FIG. 359.—Diagram of the Controlling Apparatus of a Columbia Light Electric Vehicle. A, brake pedal; B, ratchet retaining pedal in place, operated by left foot; C, dash board; D, body sill; E, steering handle; F, controller handle; G, rocker shaft for setting hub brakes; J, brake band on wheel hub; H, rear axle.

Arrangement of the Batteries and Motor Parts.—In an electric vehicle the storage batteries are arranged so as to form a number of units, the circuit wiring being so arranged that by the use of a form of switch known as a controller the connections may be varied from series to multiple, or the reverse, as desired. The same arrangement for varying the circuit connections. is used for the field windings, and, with some manufacturers, for the brush connections also. In the accompanying first diagram of the connections of an electric vehicle this fact is indicated. The dotted lines on each figure indicate the circuits that are cut out, or open, and the full lines those that are active, or closed. In the figure showing the first speed, we have the two units of the battery, *B*, connected in multiple, which means that the voltage is reduced to the lowest point. The wire, *C*, connected to the bridge between the positive poles of the battery, leads the current to the field windings, *H* and *J*, which, in this figure, are connected in series-multiple, which gives the lowest speed and power efficiency of the motors. By the wire, *D*, the current is carried to the brushes, *FF* and *GG*, which, according to this scheme, are permanently connected in multiple, the return path to the negative pole of the battery being through the wire, *A*.

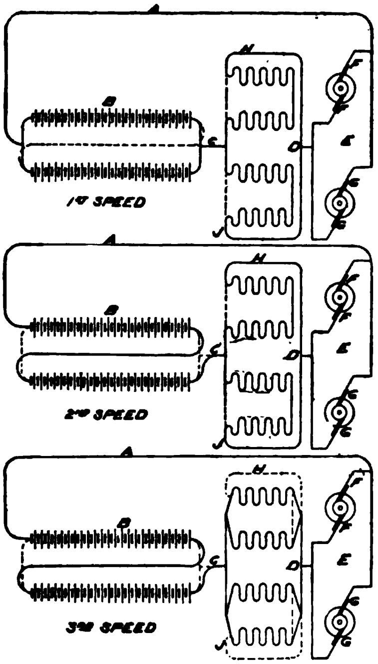


Fig. 360.—Diagram of the Circuit-Changing Arrangements of a Typical Electrical Vehicle. The full lines in these plans indicate the closed, or active, circuits; the dotted lines the open, or inactive, circuits. As may be readily understood, the whole scheme of circuit-changing depends on employing several different circuit connections between battery and motor, which may be opened and closed, as desired. Here A and C are the lead wires between battery, B, and motor brushes, F F and G G, and the field-windings, H and J, and wire, D.

In the second figure of the diagram the circuit is varied so as to connect the two units of the batteries, so as to give its highest pressure efficiency. But, since the field windings of the motors are also connected in series, or in series-parallel, as in this case, the efficiency in speed and power is reduced nearly one-half.

In the third figure the two units of the battery are connected in series, which, as in the former case, indicates the greatest efficiency in power output; but the field windings are connected in parallel, which means that the C. E. M. F., generated by their operation, is equivalent to the C. E. M. F. of only one motor, with the result that the speed and power efficiency is raised to its highest point.

Diagram of Battery, Motor and Controller.—In the second diagram, illustrating a typical method of shifting the circuits, we have the same general scheme applied, so far as the first, second and fourth speeds are concerned, the connections of the controller being laid out in rectangular form between the broken lines. When the controller is rotated, so that the row of terminal points, *A*, *B*, *C*, *D*, *E*, *F*, *G*, are brought into electrical contact with the row of terminal points, on the controller, A', B', C', D', E', F', G', we have the first speed forward, which, as may be readily discovered by tracing the connections throughout, involves that the two-unit battery is connected into multiple and the field windings of the two motors in series. Tracing the connections indicated for the second speed, we see that the terminal points, *A*, *B*, *C*, etc., are brought into electrical contact with A^2, B^2, C^2, etc., and we have the batteries in multiple and the fields in series-multiple. Tracing the connections indicated for the third speed, we have the terminal points, *B* and *C*, connected to the terminal points, B^3 and C^3, and the terminal points, *E* and *F*, connected to the terminal points, E^3 and F^3, which means that the batteries are connected in series and the fields in series. Similarly, by tracing the connections for the fourth speed, we find the terminal points, *B* and *C*, connected to terminal points, B^4 and C^4, and the terminal points, *D*, *E*, *F*, *G*, in electrical connection with the terminal points, D^4, E^4, F^4, G^4, which means that the batteries are in series and the fields in multiple. The connections between the battery, the armature brushes and the motor fields, are made as indicated through the

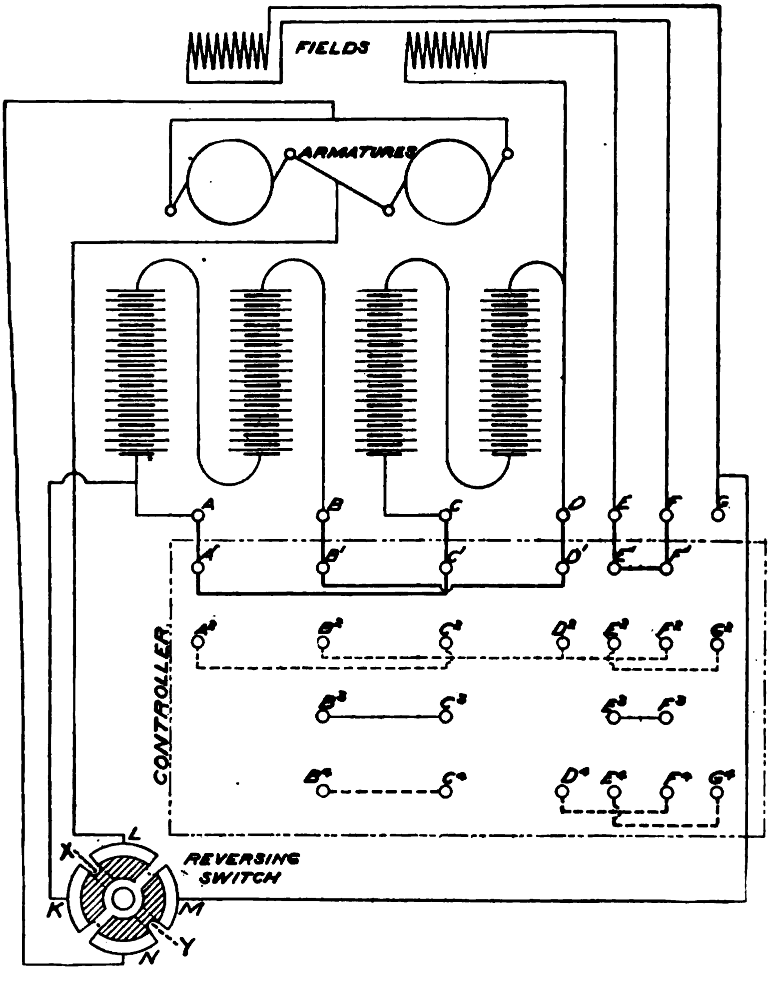


FIG. 361.—Diagram Plan of the Several Parts of an Electrical Vehicle Driving Circuit. The field-windings and armatures are shown projected, the proper wiring connections being indicated. The periphery of the controller is laid out within the broken line rectangle, the contacts and connections through it for varying the circuits through four speeds being shown. A, B, C, D, E, F, G are the terminal contact points of the various speed circuits, to be made as the positions of the controller contacts are varied. A′, B′, C′, D′, E′, F′ are the controller contacts, which, with those already mentioned, make the proper circuits for the first speed. Similarly, A^2, B^2, C^2, etc., when brought into contact with A, B, C. etc., give the second speed circuits; B^3, C^3, E^3, F^3, in contact with A, B, C, D, etc., give the third speed; and B^4, C^4, D^4, in the same manner, the fourth speed. The reverse switch gives the backward movement, as described.

rotary reversing switch, by the terminals, *K*, *L*, *M*, *N*. This switch may effect the reversal of the motors by giving a quarter turn to its spindle, which means that the contacts of segment, *X*, will be shifted from *L* and *K* to *K* and *N*, and the contacts of segment, *Y*, shifted from *M* and *N* to *L* and *M*, thus reversing the direction of the current.

Electric Vehicle Company's Circuits.—Some leading manufacturers of electric vehicles, notably the Electric Vehicle Co., vary the scheme shown in the last two figures by connecting the armature brushes and fields of each motor into series, and shifting the circuit connections, where two motors are used, from series to series-parallel. In the figure showing the combination of one battery unit with two motors, the connections for the three speeds obtained are obvious. Since only one unit is used, the lowest pressure of the battery can be obtained only by inserting a resistance coil, *R*, in the circuit, with the armature brushes,

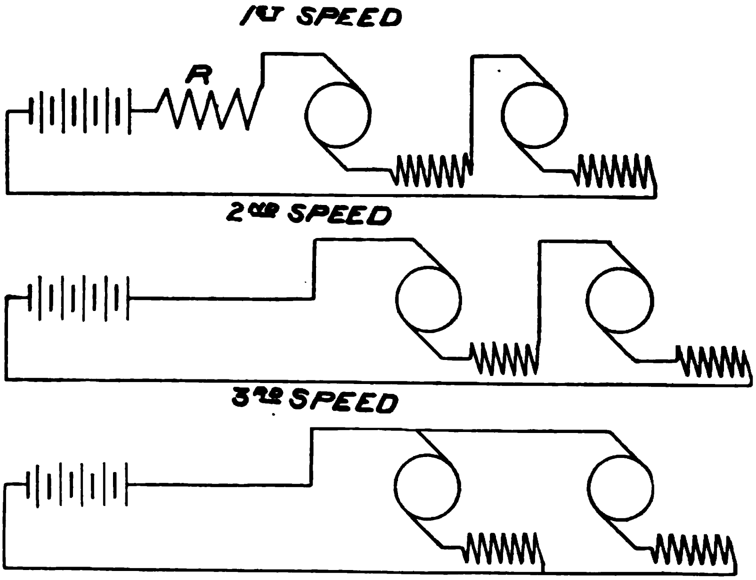


Fig. 362.—Diagram of a Typical One-Battery-Unit, Two-Motor Circuit. The first speed shows the two motors *in series*, with a resistance coil interposed; the second, the motors *in series*, without the resistance; the third, the motors *in multiple*.

field windings and both motors connected in series. For the second speed the resistance is simply cut out, allowing the full voltage of the battery to pass through the armatures and windings of both motors, still connected in series. For the third speed the connections of armatures and motors are shifted to multiple, or series-multiple. With the use of a two-unit battery and two motors, it is possible to eliminate the resistance coil altogether and depend entirely upon circuit shifting regulating the voltage and power. Accordingly, for the first speed we have the batteries connected in multiple, and the armatures and windings of the two motors in series. For the second speed,

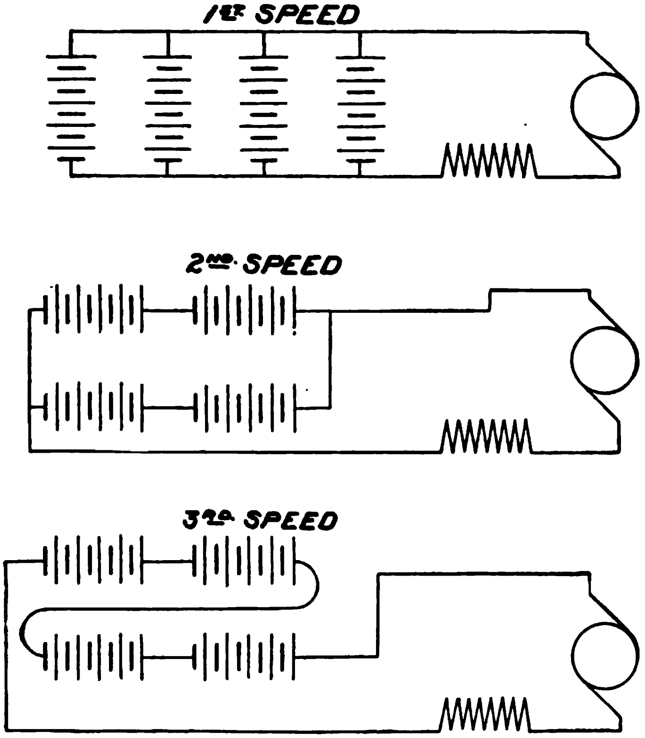


FIG. 363.—Diagram of a Typical Four-Battery-Unit, Single-Motor Circuit, showing combinations for three speeds. The only changes made in these circuits are in the battery connections. For the first speed the battery units are *in multiple;* for the second, *in series-multiple;* for the third, *in series.* The motor connections are not varied.

the series connections are adopted for both batteries and motors, while for the third speed the batteries are in series, with the motors in parallel.

A Four-Battery-Unit, One-Motor Circuit.—In the diagram indicating the use of four-battery-units with one motor, which, as shown in an accompanying cut, is used to drive both rear wheels of the wagon through a single reduction, it is possible to obtain

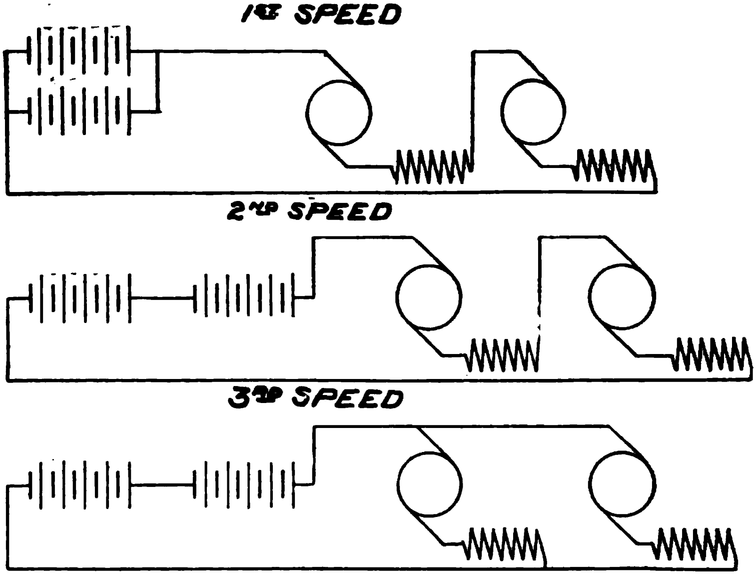


FIG. 364.—Diagram of a Two-Battery-Unit, Two-Motor Circuit, showing combinations for three speeds. The first speed is obtained with the battery units *in multiple*, and the motors *in series*; the second, with the battery units *in series*, and the motors *in series*; the third, with the battery units *in series*, and the motors *in multiple*.

a still greater range of variation by the simple shifting of the battery circuits, without alteration of the armature or field connections. Accordingly, for the first speed we have the four units connected into parallel, which gives a total voltage equivalent to the voltage of any one of them. For the second speed, the battery units are connected into series, the two pairs thus formed being joined in multiple, with the result that the total voltage of the battery is equivalent to the sum of the voltage of two of the units, or twice the voltage used in the first speed. For the third speed, all four units of the battery are connected into series, thus doubling the voltage again, and realizing the highest speed and power efficiency possible in the combination.

Vehicle Circuit Arrangements.—The next two figures illustrate different methods of arranging the circuits of an electric vehicle in actual practice. In the first, which shows the arrangements used on light Waverley carriages, the one-unit battery in three trays is shown connected in an invariable series circuit, giving the first, or lowest, speed through the resistance coil between controller contacts, 1 and 2, the motor-fields being in series; the second speed with the same circuit without the re-

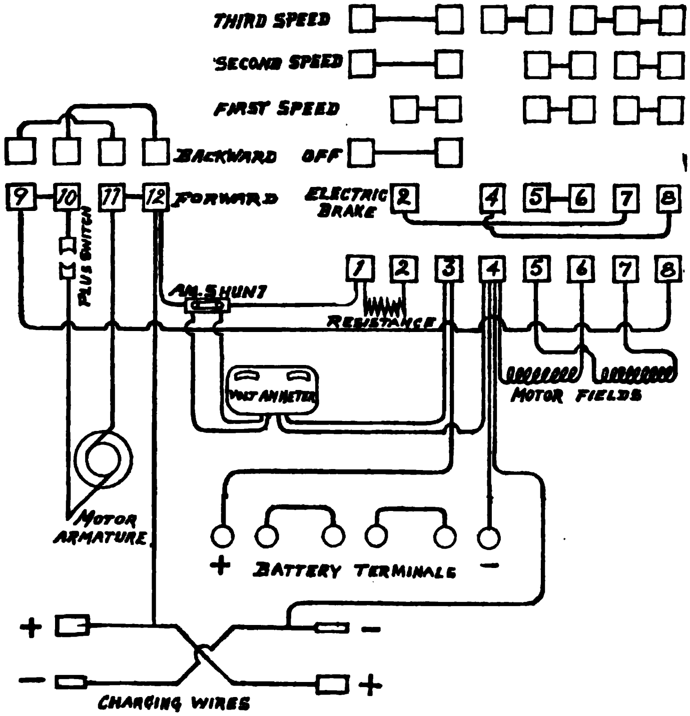


FIG. 365.—Diagram of Controller Connections of a One-unit, One-motor Circuit, with Variable Fields.

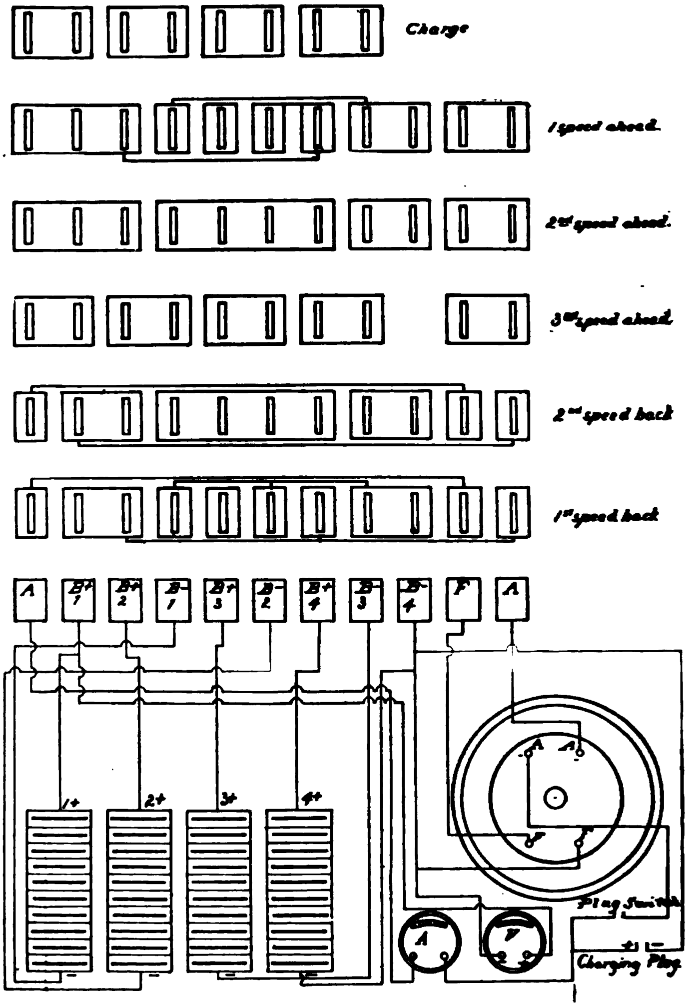


FIG. 366.—Diagram of Controller Connections of a Four-unit, One-motor, Circuit, with Constant Series Connections for Fields and Armature in Forward and Backward Speeds.

sistance, and the third speed with the motor-fields in parallel. The motor used on these carriages is of the six-pole type, the field coils being divided into two halves of three coils each, each half being independently connected to the controller contacts, as shown in the cut. Reversal is by a form of rotatable switch, and an electric brake is also used, which operates on the principle of reversing the polarity between the armature and field windings. In the second diagram is shown the connections of a series motor, in which the field and armature windings are in invariable series connections for all forward speeds. The first, or lowest, speed forward is obtained with three units of the battery in series-multiple; the second, with the four units in series-multiple; the third, with the four units in series. In reversing, the first and second speeds backward correspond to the forward speed arrangements similarly numbered, with the exception that the connections of field and armature are reversed, as may be readily understood from following out the indicated connections. In the charging position, the three contacts at the right side of the controller are cut out, leaving the battery to be charged in series from the charging plug connections to contact, *A*, at the left of the controller, to the similar connections with the negative pole of battery, 4.

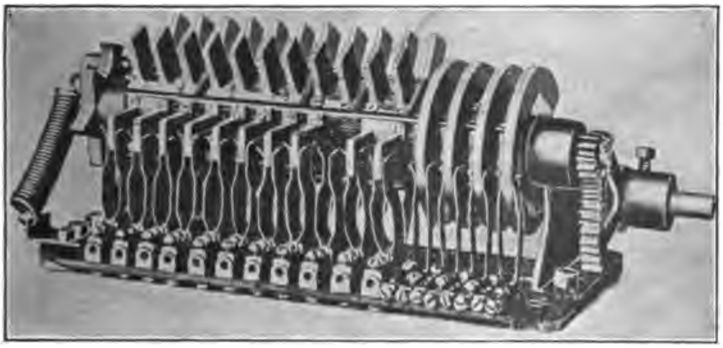


FIG. 367.—A Typical Electrical Vehicle Controller, or Circuit-changing Switch. The circuit terminals of battery and motors are shown at the jack-springs, which are arranged to be engaged by the fins on the periphery of the controller-cylinder. The connections within the controller, between the fins, are the same as those shown in Fig. 366, except for the fact that the four rings at the right hand end provide constant voltage connections for use with a shunt motor. The gaps at the rear of the rings show means for cutting out the shunt field at top speed.

The Controller of an Electric Vehicle.—The controller of an electric vehicle consists of a rotatable insulated cylinder, carrying on its circumference a number of contacts, arranged to make the desired connections with the terminals of the various apparatus in the circuit through a wide range of variation. As shown in the figure of the arrangement of the battery and controllers in a typical electric vehicle, these points are disposed so that the units of the battery may be connected in series or multiple, and that the field windings of the motors may be similarly varied. As shown in the diagram, this act is accomplished by a series of variations of electrical connection among the contact points on the periphery of the controller. Thus we find that for the first speed, in which the batteries are connected in multiple, the points, *A'*, *C'*, are in electrical connection, as indicated by the lines between them, so that the points, *A*, *C*, connected to the like poles of the two battery units, are directly connected, thus bringing the two units into multiple. The battery circuit is completed by the electrical connection on the controller between the points, *B'* and *D'*, when they are brought into contact with the points, *B* and *D*, which connect to the two other poles of the battery. Furthermore, the points, *E'* and *F'*, being in electrical connection through the body of the controller, connect points, *E* and *F*, direct, thus throwing the field windings of the

FIG. 368.—Typical Controller of the General Electric Co., showing means for making circuit connections through conducting segments on the periphery of the controller-cylinder.

motors into series. As may be understood from the last two diagrams of vehicle circuits, the contacts may be arranged to make any of several schemes of circuit variation, although, as must be obvious on examination, a specially arranged controller is necessary for each separate scheme.

Construction of a Controller.—The accompanying cuts show the general appearance and construction of several types of controller for electrical vehicles. As may be seen in the first cut, the connections of the terminals of the batteries, of the field windings, and other elements of the circuit, are made at the binding posts at the front base of the instrument. From each of these binding posts, which are electrically insulated from one another, jack-springs rise to a position convenient to make connections with the switch blades arranged along the periphery of the controller cylinder. These switch blades, as may be seen, are secured to the controller cylinder by screw connections, be-

Fig. 369.—Chassis of a Heavy Wagon of the Electric Vehicle Co., showing arrangement of controlling apparatus.

ing arranged singly, or several of them together on one plate. In the case of a pair of blades, shown in contact with the spring at either extremity of the controller cylinder, it is evident that there is an electrical contact, through the base plates, between the two terminals, represented by the contact springs in engagement. Between these two end plates, as may be seen, there are several switch blades arranged singly upon the circumference. At one point there is no contact whatever, showing that the terminals represented by the contact springs at that point are out of circuit. These several blades that are arranged singly on the controller surface have such electrical connections as the scheme of circuit variation adopted demands, made through insulated wire connections arranged between any pair it is desired to connect. This is the arrangement indicated in the diagram of connections already described. It is perfectly easy to understand, therefore, how the circuit arrangements of battery units and motor windings may be varied through any desired range of connections, by simply connecting their terminals through properly arranged and connected controller contacts.

Varieties of Controller.—The controller shown in the cut, already described, represents only one type of this machine. Some controllers are constructed simple, with a perfectly cylindrical surface, upon which bear single leaf springs, the desired electrical connections being made by suitably connected conducting surfaces on the cylinder circumference, and cut-outs being similarly accomplished by insulating surfaces, bearing against the spring contacts at the desired points. This type of controller is shown in the second cut, and is one of the most usual forms for motor vehicle purposes. As is perfectly obvious, it is possible to so arrange the electrical connections on the controller surfaces, that by proper contacts with the terminal springs, reversal of the motor may be accomplished, as shown on the last circuit diagram. This is done in a number of controllers, the reverse being accomplished at a definite notch on the quadrant of the shifting lever.

CHAPTER THIRTY-ONE.

THE CONSTRUCTION AND OPERATION OF STORAGE BATTERIES.

Storage Cells Not Condensers.—As already stated, electric vehicles derive their power from storage batteries, which are charged from a suitable charging plant, supplying current either from the street power lines, or from the dynamo operated by any convenient source of power. The word, storage battery, as applied to electrical accumulators, or secondary batteries, is somewhat of a misnomer, since these devices are in no sense receptacles for electrical energy, and act on an entirely defferent principle from the instrument known as a condenser, which depends solely upon such variations of the electrical potential between two surfaces, that one of them may be so affected by the electrical current, momentary or prolonged, as to give forth electrical energy in the form of a shock, when brought into contact with any other surface having a low or negative potential. Such a device as this is, of course, useless for any purpose requiring a constant current between two points of different potential, such as is required for any kind of power transmission.

Cells, Primary and Secondary.—The so-called electrical accumulator, or storage battery, more properly to be described as a secondary battery, operates on an entirely different principle, to be briefly described as an electro-chemical, by which a direct electric current, steadily flowing through a given period, can produce certain chemical changes, which, as the expression is, "charge" the battery. This process may be briefly illustrated by making a comparison with a primary galvanic cell. In such cells two electrodes of dissimilar substances, such as copper and zinc, or carbon and zinc, are immersed in a liquid solution, in the first case of dilute sulphuric acid, in the second of sal ammoniac—although different solutions are used in the various makes of cells. As soon as the two electrodes, thus immersed in the liquid, are connected by a wire outside of the solution, so as to form a complete circuit between them through the liquid and back again through the outside wire, an electrical current, which is to say, a continuous transmission of electrical energy, is set up. This phenomenon takes place in accord with what may be called the specific potential of the two metals. This means that if two such substances, copper and zinc, or carbon and zinc, be brought into contact *in the air,* there will be a distinct impartation of energy from the former to the latter in each case, showing that carbon and copper receive and give off a charge much more readily than zinc. On the other hand, when two such substances are immersed in the electrolytic solution the conditions are completely reversed, the impartation of energy *through the liquid* being *from* the zinc to the copper or carbon. Thus, the typical galvanic cell is really a combination of the phenomena taking place both in air—on the outside wire, between the portions of the two plates not wet with solution—and through the electrolyte. This renders the galvanic circuit possible. It also explains the fact that the zinc, or positive plate in the solution, is the negative terminal of the outside wire.

The Operation of a Galvanic Cell.—In an assembled galvanic cell of any type the operations taking place before the circuit of the outside wire is closed are purely chemical; only when the circuit is closed does electrical energy begin to manifest itself in the form of current. The same chemical processes then continue, with the result, however, of doing useful work. The first result of closing the circuit is the decomposition of the electrolyte into its component parts. If it is dilute sulphuric acid (H_2 SO_4), the decomposition is into hydrogen, oxygen and sulphuric oxide—the oxygen uniting with the zinc and gradually consuming it, and the hydrogen being collected on the face of the copper plate in the form of minute bubbles. In practical cells it is necessary to use some substance, known as the "depolarizer," that has a high affinity for hydrogen, in order that the hydrogen may be constantly absorbed and the process allowed to continue until the zinc is exhausted. Were it possible to "restore" a primary chemical cell, so that the zinc oxide would again become metallic zinc, and the electrolyte be re-composed from its elements, we would have a very fair duplication of the conditions theoretically found in a secondary, or storage, cell—except for the fact that in the latter the processes taking place on the outside wire are the same as those occurring in the electrolyte in the primary, and *vice versa*. This means that the hydrogen collects on the plate connected to the negative lead, while the destructive chemical changes occur in that connected to the positive lead of the outside circuit

The General Theory of Storage Batteries.—The general theory upon which a secondary battery operates was discovered as early as 1801, when Gautherot discovered that if two plates of platinum or silver, immersed in a suitable electrolyte, are connected to the terminals of an active primary cell and current is allowed to flow for any desired period, a small current could be obtained on an outside circuit connecting these two electrodes, as soon as the primary battery had been disconnected. The process which takes place in this case is briefly as follows: An electrolyte, consisting of a weak solution of sulphuric acid, permits ready conduction of the current from the primary battery, the greater the proportion of acid in certain limits the smaller being the resistance offered. The effect of the current passing through the electrolyte is the decomposition of the water, which is indicated by the formation of bubbles upon the exposed surfaces of both electrode sheets, these bubbles being formed by oxygen gas on the plate connected to the positive pole of the primary battery, and hydrogen on the plate connected to the negative pole of the battery. Because, however, the oxygen is unable to attack either platinum or silver under such conditions, the capacity of such a device to act as an electrical accumulator is practically limited to the point at which both plates are covered with bubbles. After this point the gases will begin to escape into the atmosphere. In this simple apparatus, as in the storage cells manufactured at the present day, the prime condition to operation, is that the resistance of the electrolyte should be as low as possible, in order that the current may pass freely and with full effect between the electrodes. If the resistance of the electrolyte is too small, the current intensity will cause the water to boil rather than to occasion the electrolytic effects noted above.

As soon as the current from the primary cell is discontinued, and the two electrode plates from the secondary cell are joined by an outside wire, a small current will be caused to flow upon that outside circuit by the recomposition of the acid and water solution. The process is in a very definite sense a reversal of that by which the current is generated in a primary cell. Hydrogen collected upon the negative plate, which was the cathode, so long as the primary battery was in circuit, is given off to the liquid immediately surrounding it, uniting with its particles of oxygen and causing the hydrogen, in combination with them, to unite with the particles of oxygen next adjacent, continuing the process until the opposite positive plate is reached, when the oxygen collected there is finally combined with the surplus hydrogen, going to it from the surrounding solution. This chemical process causes the current to emerge from the positive plate, which was the anode, so long as the primary battery was in circuit. The current thus produced will continue until the recomposition of the gases is complete; then ceasing because these gases, as before stated, do not combine with the metal of the electrodes.

Requirements in a Practical Storage Battery.—In order to produce a secondary battery that shall be able to give forth a current of sufficient strength and duration for practical purposes, it is necessary to employ some metal that can be attacked by the oxygen produced in the process of "charging," but which at the same time is capable of being restored to its normal condition when the operation is reversed and current is taken off from the cell. Hitherto, the substance found most suitable for this purpose has been lead, which, until the perfection of Edison's iron-nickel cell, has been in practically universal use for the plates and grids of storage batteries. Of course, under operative conditions, the restoration of the metal is not perfect; also, continual chargings and dischargings inevitably result in the breaking-down of the plates, involving that they be replaced.

The Plante Secondary Cells.—About 1860 Gaston Planté, a French electrician, perfected the first practical storage cell constructed by folding together spirally two sheets of metallic lead, separated by a thin septum of canvas or a strip of gutta percha and immersed in a weak solution of sulphuric acid. When a current from a primary battery is passed through the electrolyte between the two lead sheets, the same process takes place as was described in connection with Gautherot's primitive platinum cell. Oxygen and hydrogen, liberated by electrolysis, collect upon the surface of the plates, thus forming the electro-chemical basis for the production of a current, so soon as the primary electrical source is disconnected. The operation differs, however, from that formerly noted, in the fact that oxygen bubbles do not appear upon the surface of the anode, but effect a chemical change in the plate. The oxygen attacks the lead, forming lead peroxide. By disconnecting the primary source a weak current can be produced from this cell, until the normal conditions have been restored, as previously explained; but, in order to fit it for any kind of practical use, it must be suitably "formed," which process

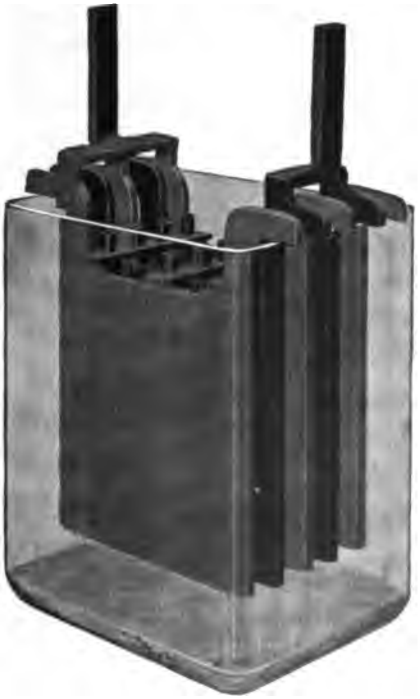


Fig. 370.—A Typical Storage Cell Enclosed in a Glass Jar. This cell represents one of the best-known makes of the Plante genus. With five plates, as shown, such a cell has a capacity of 80 ampere-hours, at 8 hours' discharge; of 70 ampere-hours, at 5 hours' discharge; of 60 ampere-hours, at 3 hours' discharge, with a discharge rate of 10 amperes in 8 hours; of 14 amperes in 5 hours, and of 20 amperes in 3 hours. The total outside dimensions of this cell are 5⅛x9½x11¼ inches; dimensions of each plate's active surface, 7¾x7¾ inches.

originally consisted in applying a charging current, first in one direction, then in the other, and allowing a discharge to follow in each case. In this process, which should occupy about two months, the following series of changes take place: The lead peroxide collected on the surfaces of one of the sheets, gradually disappears, as directed by the change in the color from brown to lead metallic. The peroxide, however, gradually begins collecting on the surface of the other plate, and so continues so long as the current endures. A plate from which the peroxide has been separated, by repeated alternations of the charging current, assumes a spongy character, which enables the augmentation of its electrical accumulating property by increasing the surface exposed to the attacks of the oxygen gas. This process of "forming" by repeated alternations of the charging current, produced a high standard of efficiency; the average power output of the earlier types of the Planté cell having been 7¼ ampere-hours per pound of lead, which is as good as has since been achieved. However, it rendered the plates very nearly rotten by the time the maximum capacity had been achieved. As a consequence the later types of this variety of cell are composed of plates formed by pickling baths of 50 per cent. solution of nitric acid. After an immersion of from 24 to 48 hours in this solution, they are treated with a 10 per cent. solution of sulphuric acid, or by a thorough washing in ammonia, followed by heating in a furnace to a temperature of 203 degrees Centigrade. Other processes, generally of a secret nature, are also used to further prepare the plates. After this they are in a condition to be used in a practical secondary battery, the process and conditions of charging being essentially the same, as have already been described.

A typical American storage cell of the Planté genus is shown in the several accompanying illustrations, which serve to show the essential features of this variety of accumulator. Both the positive and negative plates are constructed with a large number of deep parallel grooves, cut by means of a special tool. This process is termed "spinning." In order to "form" the battery the plates, thus suitably grooved, are placed in a strong oxidizing solution, generally ammonia nitrate, after which the current is passed through the solution transforming the oxides into peroxides. This treatment is continued until the entire space between the leaves is filled with active material. The formed plates are reformed as negatives to cast off nitrates, then washed as a further protection against nitrates. Plates intended for positives are reformed in a sulphuric acid electrolyte. After these processes, the positive and negative plates may be assembled into cells, the necks being burned on, so as to connect each one to its respective terminal, the cells formed by a number of these plates —an odd number of positives and an even number of negatives—have sheets of porous hard rubber between each pair of plates.

With batteries of this make, intended for use in electric vehicles, a voltage output of from eight to ten watts per pound of total battery weight may be realized. The duration of its period of usefulness is also considerably longer than that realized in many other types of cell, which is a quality claimed for several of the most representative batteries of the Planté genus.

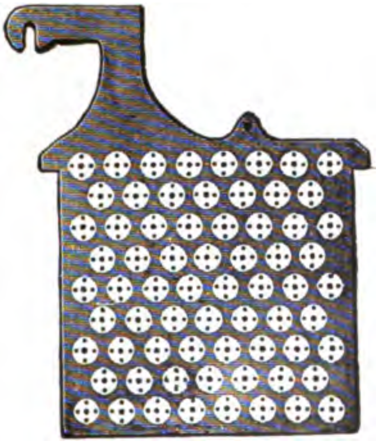


FIG. 371.—One Plate, or "Grid," of a Type of Storage Cell constructed by inserting buttons or ribbons of the proper chemical substances in perforations. Some such cells use crimped ribbons of metallic lead for inserting in the perforations, others pure red lead or other suitable material

The Faure Secondary Cells.—The Faure cells, first invented in 1881, differ from the original Planté variety in the fact that the process of forming is largely done away by "pasting," or applying active material directly to the surfaces of the plates, or "grids," in pockets or perforations. This involves that the lead grids be specially prepared for the purpose, and designs in large variety, intended to increase the active surface, while maintaining the strength of the structure, have been used by as many different inventors and manufacturers. One trouble with many such pasted cells has been that the grids are heavy in proportion to the amount of active surface exposed, and, that they are liable to warp or buckle, allowing portions of the active substance to fall between adjacent plates, short-circuiting the cell. The substances most often used in the Faure type of cell are *minium* or red lead oxide ($Pb_3 O_4$) and lead monozide or *litharge* ($Pb O$). The former under the action of the electrolyte becomes the so-called "red lead salt," the latter, the "buff lead salt." Some cells using grids with perforations for holding the active material are made somewhat differently. Thus, as stated by several authorities, in a type of cell widely used in America the positive plates or "grids" are composed of an alloy of lead and antimony, cast into shape with a certain number of round perforations. Each of these holes is then filled with a button, made by rolling a crimped lead ribbon into a coil of proper size to fit it tightly. By an electro-chemical process, the required lead oxide is then produced. The negative grids are made of casting the proper shape, under heavy pressure, around a number of square blocks of fused chloride of zinc and chloride of lead. When the grid is completed, the zinc is chemically removed, leaving the contents of each perforation pure spongy lead. The plates are now ready to be assembled into a cell and to begin work as soon as the current has passed through the electrolyte composed of a solution of sulphuric acid. Cells specially adapted for automobile work are produced by the same manufacturers.

The series of operations taking place during the charge or discharge of a storage cell are very complicated, and need not be fully discussed at the present time. It is desirable, however, to outline them in a general way. In discharging a cell the oxygen in the electrolyte attacks the spongy surface of each negative plate, releasing hydrogen, which, in turn, reduces the lead peroxide or dioxide (PbO_2) of each positive plate to monoxide ($Pb O$). The surplus radical of the acid then combines with the active material on both plates, producing sulphates and thus reducing the specific gravity of the electrolyte. Although this "sulphating" of the plates is a common and necessary part of the process of discharge, it is a source of trouble, if allowed to become excessive, as in an overdischarge—below 1.8 or 1.75 volts. In charging, the current passes from the each positive plate through the electrolyte to the negative, exerting the effect of decomposing the sulphate and transferring all the oxygen from the negative to the positive plates. The negative plates are thus freed from oxide, becoming merely spongy or porous metallic lead; while the positive plates contain no oxides lower than the peroxide, with the probable addition of some sulphates. Owing to the decomposition of the sulphates, the specific gravity of the electrolyte is at its highest on completion of the charge. The limit of charging capacity is carefully determined for each type of cell, but may be readily recognized by the giving-off of oxygen and hydrogen gases. The condition of the plates may also be known by their color. Thus, at full charge the positives are dark brown and the negatives, dark slate colored; at discharge the positives are chocolate brown and the negatives, light slate colored. The specific gravity of the electrolyte also gives an indication on this point, as above suggested. Sulphating and over-discharge are indicated by a drab color of the positive plates.

Considering only the reactions that affect the active materials, we have the following formulæ, as given by several authorities:

In charging

POSITIVE PLATES.

$$PbSO_4+SO_4+2H_2O=PbO_2+2H_2SO_4.$$

NEGATIVE PLATES.

$$PbSO_4+2H=Pb+H_2SO_4.$$

In discharging

POSITIVE PLATES.

$$(1)\ PbO_2+2H=PbO+H_2O.$$

$$(2)\ PbO+H_2SO_4=PbSO_4+H_2O.$$

NEGATIVE PLATES.

$$Pb+H_2SO_4=PbSO_4+2H.$$

Combining these equations, we have the "practical universal equation," as given by several authorities:

$$PbO_2+2H_2SO_4+Pb=2H_2O+2PbSO_4.$$

This means simply that a combination of lead peroxide (1 part), metallic lead (1 part), sulphuric acid (2 parts), gives, in process of discharge, water (2 parts) and lead sulphate (2 parts)—the process being reversed during charging.

For a cell previously charged, and using red lead salt as the active material, the following series of changes are given by Frankland and quoted by other authorities:

In charging

POSITIVE PLATES.

$$S_2Pb_3O_{10}+O_2+2OH_2=3PbO_2+2SO_4H_2.$$

NEGATIVE PLATES.

$$S_2Pb_3O_{10}+4H_2=3Pb+2SO_4H_2+2OH_2.$$

In discharging

POSITIVE PLATES.

$$3PbO_2+2SO_4H_2+2H_2=S_2Pb_3O_{10}+4OH_2.$$

NEGATIVE PLATES.

$$3Pb+2SO_4H_2+2O_2=S_2Pb_3O_{10}+2H_2.$$

Points on Care and Operation.—On the manner of operating and maintaining storage batteries for use in electric vehicles and for other purposes, there are a number of points to be considered.

However, since full directions are always furnished by manufacturers with each set of cells, it is necessary to give only the merest outlines here. Nearly the most important matter for the beginner to understand thoroughly is that relating to the preparation and use of the electrolyte. As has been already stated, this consists of 1 part of chemically pure concentrated sulphuric acid mixed with several parts of water. The proportion of water differs with the several types of cell from 3 parts to 8 parts, as specified in the directions accompanying the cells. In making the mixture it is necessary to use an hydrometer to test the specific gravity of both the acid and the solution. The most suitable acid should show a specific gravity of about 1.760, or 66° Baume.

The mixture should be made by pouring the acid slowly into the water, never the reverse. As cannot be too strongly stated,

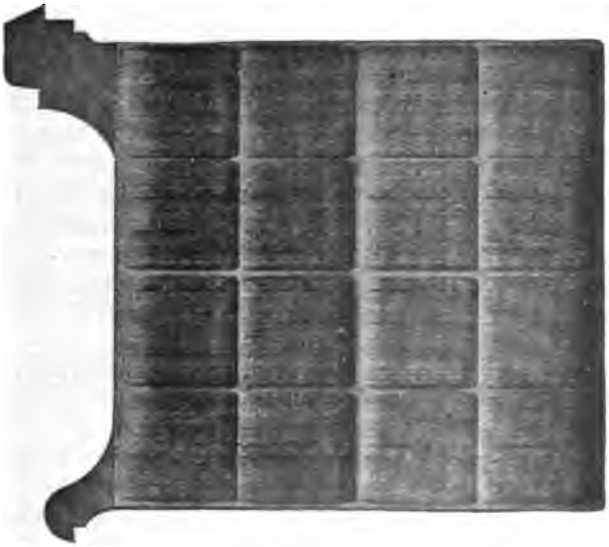


FIG. 373.—Specimen Negative Plate of a Type of the "Gould" Storage Battery, showing the result of "formation" in the changed appearance of the plate surface.

FIG. 374.—Specimen Positive Plate of a Type of the "Gould" Storage Battery, showing the changed appearance of the plate surface, due to "formation."

become lodged between the plates, it may be removed by a wood or glass instrument. If some of the active material has scaled off, it may be forced down to the bottom of the jar. If excessive sediment is found, the jar and plates should be washed carefully, and reassembled. A cell that has been short-circuited may be disconnected from the battery and charged and discharged several times separately. This may remedy the trouble.

In placing the electrolyte in jars containing the cells, special care should be taken that the entire active surface of the grids is completely submerged. They should always be at least one-half inch below the surface of the solution. Whenever it is necessary to renew the electrolyte this rule should be observed, and so long as the batteries are in operation the level should never be allowed to fall below the points specified.

Connections for Charging.—In charging a storage battery, it is of prime importance that the connections with the generator be properly arranged. This means that the positive pole of the generator should be invariably connected to the positive pole of the secondary battery—which is to say, the pole which is positive in action when the current is emerging from the secondary battery, or the pole that is connected to the positive plates. As this is a matter of prime importance, the exact polarity of both generator and secondary battery terminals should be accurately determined before attempt is made to charge. An error in this particular will result in entire derangement of the battery and its ultimate destruction. In charging a storage battery for the first time it is essential that the current should be allowed to enter at the anode or positive pole at about one-half the usual charging rate prescribed; but after making sure that all necessary conditions have been fulfilled, it is possible to raise the rate to that prescribed by the manufacturers of the particular battery.

Period of Charging a New Battery.—With several of the best known makes of the American storage battery the prescribed period for the first charge varies between twenty and thirty hours. The manufacturers of a well-known cell of the Planté genus prescribe for the first charge half rate for four hours, after which the current may be increased to the normal power and continued for twenty hours successively.

The strength of current to be used in charging a cell should be in proportion to its own ampere-hour capacity. Thus, as given by several manufacturers and other authorities, the normal charging rate for a cell of 400 ampere hours should be fifty amperes; or one-eighth of its ampere-hour rating in amperes of charging current. Before closing the charging circuit it is essential that the voltage of the generator should be at least ten per cent. higher than the normal voltage of the battery when charged. The fact that a storage cell is fully charged is evident by the apparent boiling of the electrolyte and a free giving-off of gas. It may also be determined by the voltmeter, which will show whether the normal pressure has been attained. At the first charge of the battery, the voltage should be allowed to rise somewhat above the point of normal pressure, but thereafter should be discon-

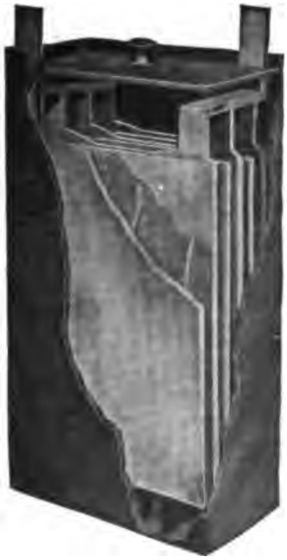


Fig. 375.—One Cell of the "Gould" Storage Battery for Electric Vehicle Use. According to the data given by the manufacturers, this cell, containing four negatives and three positive plates, has a normal charging rate of 27 amperes; a distance rate of 22½ amperes for 4 hours; a capacity of 81 ampere-hours at 3 hours' discharge, and of 90 ampere-hours at 4 hours' discharge. The plates are each 5⅞x7¾ inches, and the total dimensions of the cell, enclosed in its rubber jar, are 2½x6¼x11 inches. Forty such cells are generally used for an average light vehicle battery.

tinued at a specified point. At the first charging of a cell, when the pressure has reached the required limit, the cell should be discharged until the voltage has fallen to about two-thirds normal pressure, when the cell should again be recharged to the normal voltage (2.5 or 2.6 volts).

Changed Specific Gravity of the Electrolyte.—Another effect resulting from the first charging of a storage cell is a change in the specific gravity of the electrolyte. According to the figures already given, this should be about 1,200, when the solution is first poured into the cells. At the completion of the first charge, it should, on the same scale, be about 1,225. If it is higher than this, water should be added to the solution until the proper figure is reached; if it is lower, dilute sulphuric acid should be added until the hydrometer registers 1,225.

In charging a storage cell, particularly for the first time, it is desirable to remember that a weaker current than that specified may be used with the same result, provided the prescribed duration of the process be proportionately lengthened. The battery may also be charged beyond the prescribed voltage, ten or twenty per cent. overcharge affecting no injury occasionally; although, if frequently repeated, it seriously shortens the life of the battery.

Another point of importance touches the question of maintaining the charge of the battery. Even if the use is only slight, in proportion to the output capacity, the battery should be charged at least once in two weeks, in order to maintain it at the point of highest efficiency. About as often a battery should be charged at slowest rate, the charging current being adjusted to complete the charge only in twenty or thirty hours.

In charging a storage battery, it is essential to remember the fact that the normal charging rate is in proportion to the voltage of the battery itself. Thus, a 100-ampere-hour battery, charged from a 110 volt circuit, at the rate of ten amperes per hour, would require ten hours to charge, and would consume in that time an amount of electrical energy represented by the product of 110 (voltage) by 10 (hours), which would give 1,100 watts.

The Capacity of Storage Batteries.—The discharge capacity of a storage battery is stated in ampere-hours, and, unless otherwise specified, refers to its output of current at the 8-hour rate. Most manufacturers of automobile batteries specify only the amperage of the discharge at 3 and 4 hours. As there is no sure way for the automobilist to estimate the discharge-capacity of his battery, he is obliged to base such calculations as he makes on the figures furnished by the manufacturers. With the help of his indicating instruments—the voltmeter and ammeter—this is a comparatively simple matter, as may be understood from the following quotation:

"It is customary to state the normal capacity of a cell in ampere-hours, based upon the current which it will discharge at a constant rate for eight hours. Thus a cell which will discharge at 10 amperes for 8 hours *without the voltage falling below* 1.75 *per cell* is said to have a capacity of 80 ampere-hours. It does not follow that 80 amperes would be secured if the cell were discharged in 1 hour. It is safe to say that not more than 40 amperes would be the result with this rapid discharge. *The ampere-hour capacity decreases with the increase in current output.* An 80 ampere-hour cell, capable of delivering 10 amperes for 8 hours, would, when discharged at 14 amperes, have a capacity of 70 ampere-hours; when discharged at 20, its capacity would be 60; and when discharged at 40, its capacity will have decreased from 80 to 40 ampere-hours. Generally speaking, the voltage during discharge is an indication of the quantity of electricity remaining within the cell."

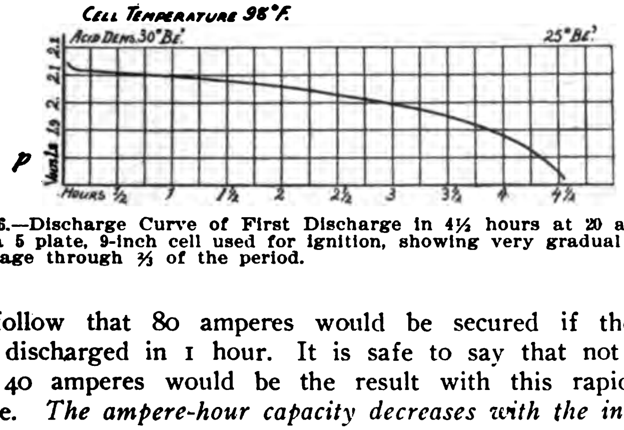


Fig. 376.—Discharge Curve of First Discharge in 4½ hours at 20 amperes of a 5 plate, 9-inch cell used for ignition, showing very gradual fall in voltage through ⅔ of the period.

In order to obtain a general idea of the comparative figures, as between the several makes of American storage cell, the following tables on sizes suitable for automobile use are given.

The manufacturer of one of the most efficient types of battery gives the following data:

Discharge in Amperes Per Hour During			Ampere Hour Capacity When Discharged in			Normal Charging Rate	Outside Dimensions of Jar in Inches		
8 Hrs.	5 Hrs.	3 Hrs.	8 Hrs.	5 Hrs.	3 Hrs.		Height	Length	Width
6¼	8¾	12½	50	43¾	37½	6¼	10½	5¼	4¼
7½	10½	15	60	52½	45	7½	11	7⅞	4¼
8¾	12¼	17½	70	61¼	52½	8¾	12½	7⅞	4¼
10	14	20	80	70	60	10	12	6⅜	7
12½	17½	25	100	87½	75	12½	12	6⅜	7
15	21	30	120	105	90	15	12½	6⅜	7
17½	24½	35	140	122½	105	17½	12½	6⅜	7
20	28	40	160	140	120	20	12½	9⅛	5¾
22½	31½	45	180	157½	135	22½	12½	9	6½
25	35	50	200	175	150	25	12½	9	6½
27½	38½	55	220	192½	165	27½	12½	9	6½
30	42	60	240	210	180	30	12½	9	6½
37½	52½	75	300	262½	225	37½	12½	9⅛	7¾
45	63	90	360	315	270	45	12½	9	8⅜
52½	73½	105	420	367½	315	52½	12½	11⅛	8

For another make of battery the same rates of discharge give the following figures:

Discharge in Amperes Per Hour During			Ampere Hour Capacity When Discharged in			Normal Charging Rate	Outside Dimensions of Jar in Inches		
8 Hrs.	5 Hrs.	3 Hrs	8 Hrs.	5 Hrs.	3 Hrs.		Height	Length	Width
7½	8½	15	60	52½	45	7½	8½	6½	9
9⅜	13⅛	18¾	75	65⅝	56¼	9⅜	8½	6½	9
11¼	15¾	22½	90	78¾	67½	11¼	8½	6½	10½
10	14	20	80	70	60	10	12½	7	9
15	21	30	120	105	90	15	12½	7	9
20	28	40	160	140	120	20	12½	8⅝	9
25	35	50	200	175	150	25	12½	10	9
30	42	60	240	210	180	30	12½	12½	9
35	49	70	280	245	210	35	12½	12½	9
40	56	80	320	280	240	40	15½	12⅝	9
50	70	100	400	350	200	50	15½	12⅝	10⅝
60	84	120	480	420	360	60	15½	12⅝	10⅝

The variation in figures between the two types mentioned is largely due to the number of plates per jar and to other points of construction. Apart from any considerations of efficiency, the driver of an electric carriage should carefully bear in mind the figures supplied by the manufacturers of the type of battery he uses, in order to judge (1) how long the present charge will last; (2) whether he is exceeding the normal rate of discharge, and thus contributing to the unnecessary waste of his battery and incurring other dangers that may involve unnecessary expense. As a general rule the 1-hour discharge rate is four times that of the normal, or 8-hour discharge, and considerations of economy and prudence suggest that it should never be exceeded, if, indeed, it is ever employed. The 3-hour discharge, which is normally twice that of the 8-hour, is usually the highest that is prudent, while the 4-hour discharge is the one most often employed for average high-speed riding. Thus, most makers of automobile batteries give only the 3 and 4-hour discharge rates in specifying the capacity of their products

FIG. 377.—Elwell-Parker Motor Generator Set for Charging Vehicle Storage Batteries. This machine has an output capacity of about 15 horse power.

High Charging Rates.—Occasionally it is desirable to charge a battery as quickly as possible, in order to save time, as when belated and far from home with an electric vehicle that has almost reached its limit. As a general, if not an invariable, rule, such a procedure should not be adopted unless the battery is thoroughly discharged, and not then, unless done by a person who thoroughly understands what he is about. As battery-makers will always furnish data and directions to meet emergencies demand rapid charging, it is unnecessary to run risks.

In charging a battery at a high rate, the danger to be avoided is the tendency of the cells to heat. The troubles that might arise from this cause may be prevented by immediately reducing the current strength. The proper rate of charge for a given battery of cells may be thus discovered by experiment. A battery should never be charged at a high rate unless it be completely exhausted, since it is a fact that the rate of charge that it will absorb is dependent upon the amount of energy already absorbed.

As given by a well-known vehicle manufacturer, the following data on discharging and rapid charging of a given make of battery will be found typical:

Ampere Hour Capacity Discharged in					Normal Charging Rate	Rate in Amperes for a 3-Hour Charge					Rate in Amperes for a 45-Minute Charge				
3 Hr.	4 Hr.	5 Hr.	6 Hr.	8 Hr.		½ Hr.	½ Hr.	½ Hr.	½ Hr.	1 Hr.	20 M.	5 M.	5 M.	10 M.	5 M.
34	38	40	42	48	6	36	20	16	10	5	72	52	36	16	5
45	50	53	55	64	8	48	28	20	16	7	96	68	48	20	7
66	73	78	81	96	12	70	40	30	20	10	140	100	70	30	10
112	124	132	137	160	20	128	68	52	32	17	238	170	119	51	17
140	155	165	171	200	25	150	86	62	42	21	300	214	150	64	21
168	186	198	206	240	30	178	102	76	50	26	356	254	178	76	26
196	217	231	240	280	35	208	118	90	60	30	420	300	210	90	30

As here shown, the 96 ampere-hour cell requires, for charging in three hours: For the first half hour, 70 amperes; for the second, 40 amperes; for the third, 30 amperes; for the fourth, 20 amperes, and during the last hour, 10 amperes. It may also be charged at the following rate in 45 minutes: 140 amperes for the first 20 minutes; 100 amperes for the next 5 minutes; 70 amperes for the next 5 minutes; 30 amperes for the next 10 minutes; 10 amperes for the last five minutes. This is the rate to be followed when the battery is completely discharged.

Such figures would undoubtedly vary for different makes of battery, but, when once known should never be departed from, except by an expert who knows perfectly what he is doing in any given case. Such a person, however, would likely be more than usually careful to observe rules. In fact, these rules are imperative, and a current of a given strength should not be continued over the time specified in the directions, nor after the voltmeter records a pressure of 2.6 volts per cell.

General Points on Care.—It is unnecessary to give a long series of minute directions on what to do and what not to do in all imaginable conditions. If the user of a storage battery will always remember that this apparatus is a very delicate one; that it will do so much in a given time, and no more; that it must be used and treated quite as carefully as a living thing; that any attempt to make it do more than experts have stated that it can do will only involve failure, disaster and expense—perhaps also danger—he will have mastered the substance of what the best-worded treatise could tell him.

When charging a battery particular care should be taken not to have a naked flame anywhere in its vicinity. This is necessary because during that process inflammable gases, principally hydrogen, are given off, and the result will be more picturesque than enjoyable. To either discharge or charge a battery at too rapid a rate involves the generation of heat. Thus, while this is not liable to result in flame under usual conditions, the battery may take fire, if it is improperly connected or improperly used.

A well-known European authority specifies three reasons for this accident:

(1) Faulty connection of conductors leading to the controller.

(2) The use of such a conductor that is so long as to lie over the battery, so that the insulation is rubbed off, causing a short circuit.

(3) Short circuit caused by acid splashed from the battery eating the insulation of such conductors.

His directions are sensible and practical: (1) Set the controller at rest; (2) open the switch or withdraw the emergency plug; (3) open the battery case and disconnect the battery from the rest of the machinery. This will cause the fire to go out of itself.

In driving an electric vehicle the battery should be saved as much as possible, particularly on steep hills and rough roads. If the amperage rises abnormally on a hill it is better to tack from side to side than to risk mishaps.

If under such conditions, the voltmeter shows a fall below 1.75 per cell, it does not necessarily indicate that the battery is exhausted or injured. However, a careful driver will stop his carriage for a few minutes, when it will be probable that the normal reading will again be shown. If this result follows often in succession, the battery had better be examined by an expert. Generally, however, it is merely the result of hard working.

Edison Battery: Theory and Construction.—The recently perfected Edison storage cell, although a departure in several particulars from the general theory of electrical accumulators hitherto recognized, may be classed with those types of battery constructed on the principle of having the plates of opposite polarity constructed of diverse materials. Among such may be mentioned the so-called lead-zinc, lead-copper and alkaline-zincate, in which one plate was formed of zinc, of copper, or other suitable substance. None of them has been used in automobile work.

Following his usual procedure, Mr. Edison started his investigations with the theory that the ideal storage cell should embody the following peculiarities:

(1) An alkaline "electrolyte"—all corrosive acids being eliminated; (2) active materials insoluble in the liquid; (3) a solution that should remain the same under all conditions; (4) immunity from deterioration or disintegration in use; (5) simplicity in the process of charging; (6) immunity from injury by overcharging or overdischarging; (7) a high rate of charge and discharge; (8) small weight per horse power per hour and constant discharge capacity through extended periods.

As the result of investigations with a wide variety of substances, Mr Edison finally constructed a cell with an oxide of iron for the negative element, and a superoxide of nickel for the positive, with a solution containing about twenty per cent. of potassium hydroxide by weight.

Mechanically, also, the construction differs from ordinary accumulators. Each grid, or plate, formed of steel, has twenty-four rectangular openings, giving it somewhat the apearance of a window. Into each of these is fitted and pressed a flat box or pocket —the one part of which engages into the other, like a box and cover, each being thoroughly perforated. The active material is placed in these boxes, the nickel in those of one grid, the iron in those of the other. The construction is thus extremely light and compact.

The Theory of Operation.—In operation, the theory involved is simply the transfer of oxygen from one material to the other—from the nickel to the iron in charging, and from the iron to the nickel in discharging. The solution furnishes merely a suitable means of transfer.

Data on Charging and Discharging.—The several sizes of cell, as at present manufactured, differ only in the number of plates and in capacity, the dimensions of the plates being the same in each case. The following table gives the general data relating to the sizes of cell suitable for automobile work:

Number of Plates.	E-18.	E-27.	E-45.
Capacity in ampere hours	105 to 115	160 to 175	260 to 280
Average discharge voltage per cell	1.23	1.23	1.23
Rates of discharge in amperes	30	45	75
Satisfactory rates of charging in amperes	40	65	100
Suitable times of charging in hours	3¼	3¼	3¼
Weights in pounds per cell complete, including solution	13	17½	28

As may be seen, the average discharge voltage is lower than in other types of cell, the available pressure being, in fact, cut down fifty per cent. The advantage realized, however, is in durability, rather than in high capacity. A battery of 32 such cells, rating 160 ampere-hours, will give at a 30-ampere discharge a travel radius of 40 miles at 15 miles per hour for a light runabout. In relation to its weight, however, the Edison cell is very much more powerful than the average of other types. According to the data furnished by Professor Kennelly, the average lead-lead cell yields between 4 and 6 watt-nours per pound weight, which is between 124.5 and 186.5 pounds per horse-power hour at its terminals, or an energy sufficient to raise its own weight through a vertical distance of from 2 to 3 miles (3.2 to 4.8 kilometres) against the force of gravity. The Edison battery, on the other hand, yields 14 watt-hours per pound weight, which is about 53.3 pounds per horse-power hour at its terminals, or an energy sufficient to raise its own weight through a vertical distance of 7 miles (11.26 kilometres).

It also embodies the advantages of being virtually uninjured by overcharge or overdischarge, and of requiring no other ordinary care than the occasional addition of pure water to maintain the proper level of the solution in the jars.

Battery-Charging Apparatus.—A storage battery may be charged from direct-current mains having the proper voltage if, as is not always possible, such a circuit is available. Since, however, a current of as great uniformity as possible is required, and existing conditions must be met in each separate case, it is the rule to use a motor-generator set with a regulating switchboard. Such an apparatus consists of a direct-current dynamo, driven direct from the shaft of a motor, which, in turn is energized by current from the line circuit. With a direct current on the line, a direct-current motor may be used; but with an alternating current an induction motor is required. The speed of the motor is governed by a theostat, and the output of the dynamo is thus regulated as desired.

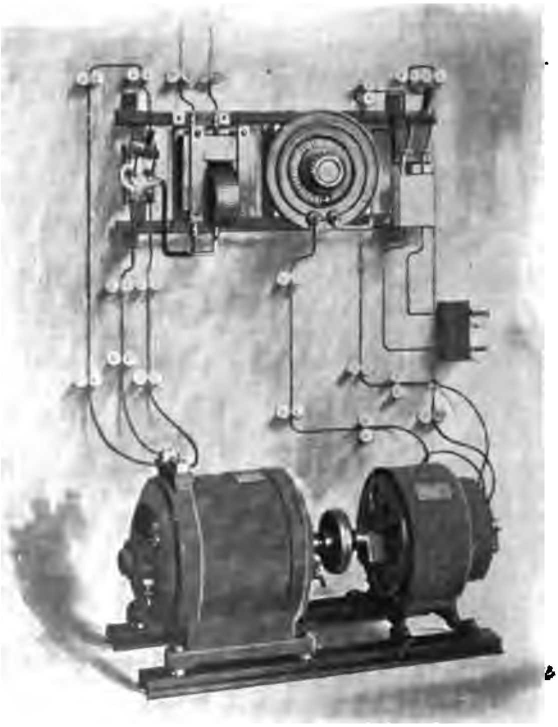
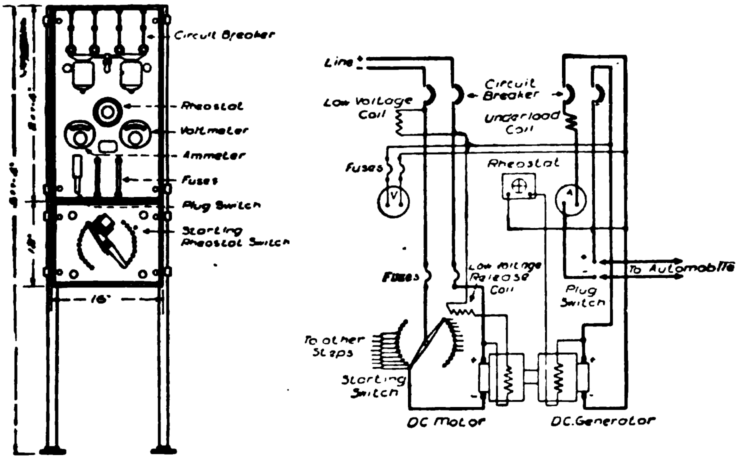


FIG. 378.—Waverley Motor-generator Charging Set for Use on a Single-phase Alternating Current Circuit of 100 to 110 Volts (60 Cycles). This apparatus will give a current of 15 amperes at 65 volts in charging a 24-cell battery, or 10 amperes in charging a 30-cell battery.

A typical outfit of this description is shown in the accompanying diagrams, which show the circuits of a switchboard and charging set, operated from both direct and alternating-current line circuit. The switchboards are equipped with a voltmeter for indicating the pressure of the generator; an ammeter for indicating the amount of current being supplied to the batteries;

an underload coil to automatically shut down the motor-generator set when the battery is fully charged; a low-voltage coil, to open the circuit on the moment of cutting off the power, thus fully protecting the motor, preventing the battery from running the dynamo motorwise and involving that the starting theostat be used whenever the motor is to be used. These operations may be performed manually by the use of circuit-breaking handles.

Method of Operating.—An idea of the procedure involved in the use of such an apparatus may be obtained from the following items furnished by the General Electric Company's outfits:



FIGS. 379, 380.—Switchboard and Motor-generator Circuit Connections for Charging a Battery from Direct Current Mains.

(1) Pull down the tripping handle of the circuit breaker and close the two outside poles which connect the motor circuit. The tripping shaft is then automatically locked so that the breaker will not reopen. Then push the core of the low-voltage coil (right-hand coil) up as far as it will go.

(2) Start the motor.

(3) Regulate the generator to give about the desired charging voltage.

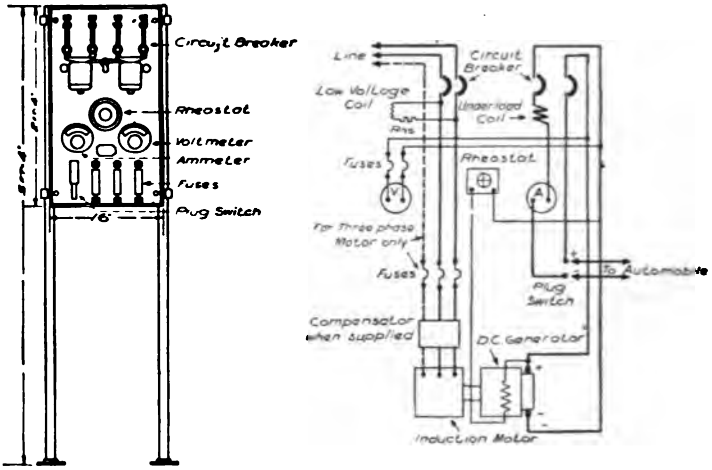
(4) Connect cable to automobile and attach to panel by means of plug switch.

(5) Raise the core of the underload coil (left-hand coil) up as high as it will go, and while holding in this position close the

other two poles of the circuit breaker. The closing of these two poles releases the lock on the tripping shaft so that the breaker will then operate on either underload or low voltage.

(6) Regulate generator voltage until ammeter indicates the normal ampere charging rate of the storage battery.

Dynamos are also furnished with a small gas engine, the speed being regulated by adjusting the intake of fuel, and the pressure and current by a suitable switchboard.



FIGS. 381, 382.—Switchboard and Motor-generator Circuit Connections for Charging a Battery from Alternating Current Mains. The connections of a third wire are shown, for use in case a three-phase circuit is available.

CHAPTER THIRTY-TWO.

STEAM AND ITS USE AS A MOTIVE POWER.

The General Situation on Steam Using.—In recognizing and applying practically the fact of the expansive energy of steam, Watt earned his title, inventor of the steam engine. All that has been done since his day is to still further enlarge on the principles applied by him: First, in the use of higher pressures; second, in such structural improvements as have rendered steam-using more economical and brought the engine to the high point of perfection it now possesses. All these improvements in the direction of enlarged efficiency have been made possible by a more perfect knowledge and closer observation of the laws governing the properties of steam at various temperatures and pressures. For, although exhibiting divergent properties in some particulars, steam may be treated and handled according to the general laws of "permanent" gases—those, such as air, oxygen, etc., which never pass into the liquid or solid states under the natural physical conditions maintaining on the earth's surface.

On Steam and Other Gases.—In treating of gases in general, we must bear in mind that modern science has apparently succeeded in *artificially* producing liquid carbonic acid gas and "liquid air"; but these results, as is well known, are achieved by the production of certain physical conditions which occur *naturally* at no place on earth. While not digressing so far as to attempt a description of the laboratory processes employed, it is not too much to say that the results are achieved by combinations of extremely high pressures and extremely low temperatures, such as must necessitate complete readjustment of molecular conditions in the gases treated. Just as permanent liquids, such as water and mercury, assume the solid state at sufficiently low temperatures, and just as permanent solids, such as iron and flint, will assume the liquid state under sufficiently high temperatures, so "permanent gases" become liquids when the produced conditions are favorable. When, on the other hand, the physical, or molecular, state of a substance is changed, the continuance of the new state depends upon the maintenance of the conditions in which it was produced. Thus, when water is changed into the vapor known as "steam," by the action of heat, it will return to the liquid state if the temperature is allowed to fall sufficiently. For this reason, it is necessary to maintain the cylinders of a steam engine at a temperature, at least, equal to that of the incoming steam. For this reason, also, it is, in general, impracticable to use steam of too high pressures—the pressure and temperature rise on a certain proportional scale—since, as cannot be avoided, the difference between its temperature and that of the cylinder walls is so great that, during the period of exhaust, a large part of it is condensed; which means that the advantage gained will sooner or later be counteracted. This brings us to a consideration of the principles governing the generation and use of steam.

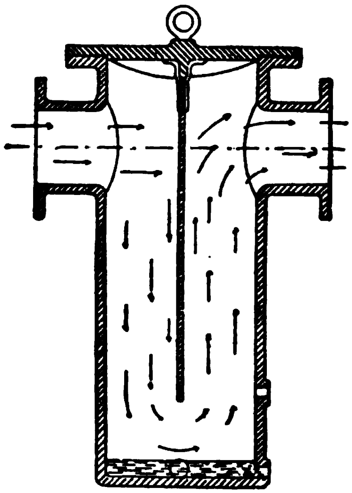


FIG. 383.—A Simple Form of Steam Separator. The steam, admitted through the port at the left of the figure, strikes against the screen in the centre of the chamber, thence following the direction of the arrows. Any condensation settles in the bottom of the chamber, whence it may be drawn off by the ports there shown.

The Conditions of Steam Generation.—According to the current hypothesis on the constitution of matter, a very essential difference between the liquid and gaseous states of matter is that, in passing from the first to the second, the constituent molecules of the substance are forced further apart. This seems to explain the fact that, when a liquid passes into a gas, it not only "evaporates" and disappears, but also fills a very much larger cubic space. Moreover, the amount of this expansion—as measured by the cubic content filled by the gas, as compared with that filled by the liquid—is in proportion to the heat under the action of which the water is vaporized. If then, a gas subjected to heat be confined in some receptacle, so that it cannot occupy the space properly belonging to it, it will show its tendency to assume that volume by exerting a pressure in proportion to the temperature in the receptacle. This is precisely what happens in a steam boiler. The steam, when liberated from confinement, will continue to exert a constantly decreasing pressure, until it has reached the volume properly resulting from its temperature, at which point the pressure will be that of the atmospheric air. It is this pressure, or natural effort to assume a greater volume—hence to displace movable obstacles—that is employed in the steam engine for producing motion and transmitting power.

The Forms of Steam.—In dealing with the general problems of steam engine operation, we must recognize two kinds of steam, or rather two conditions in which it is found and used. The first is that known as "saturated" steam, which may be defined as steam in contact with the water from which it has been generated, and which has absorbed and holds, as "latent heat," the full number of thermal units necessary to completely vaporize the liquid at the given pressure. The significance of the word, "saturated," is thus apparent—the steam holds *in solution* the full quantity of heat theoretically needed to produce and maintain it as steam. The second distinction of steam is "separated" steam, which signifies steam mechanically separated from the generating liquid, so that, when fed to the cylinder of the engine, it is perfectly *dry*. As the process of *separation* properly involves the constant maintenance of a high temperature, so that the process of condensation may be prevented, the dry steam continues to absorb heat, above the point required for this end, and thus becomes what is known as "superheated" steam.

When steam is properly separated and superheated, its expansion and other properties, so long as the initial temperature is maintained, follows closely on the laws governing the actions of permanent gases. This is true only in a limited sense of steam that is still in contact with the generating liquid; since, not only does increase of heat within the generator, or boiler, tend to continue the process of steam production within small limits, but also because the steam holds in suspension a certain amount of unvaporized liquid particles. From either or both these causes, its coefficient of expansion is larger than that of dry steam. That is to say, it undergoes a greater increase in potential volume, as indicated by the consequent rapid proportionate increase in pressure, within the generator, or heated receptacle. Another point of difference—here it is that dry steam assumes the general properties of permanent gases—is that saturated steam, when a certain high point of pressure has been reached, tends to liquefy; hence also preventing the heated water from giving off any more vapor. Dry steam may not be condensed by pressure, so long as the temperature is not lowered. On account of this law of pressures, the evaporation of water by the sun, under atmospheric conditions, is less rapid than at high temperatures; also, water enclosed in a vacuum tube, where it is subjected to no pressure, theoretically, may be boiled, producing vapor, at the temperature of the human body (96° Fahrenheit).

The Law of Pressure and Volume of Gases.—The physical properties of gases in general are defined by two familiar laws—the first defining the degrees of volume and pressure at constantly maintained temperatures; the second, the ratio of expansion at a constantly increasing temperature. The first, known as Boyle's Law, 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.

This law has frequently been illustrated by the following experiment:

If we take a hollow cylinder, such as is used on steam engines, having a piston sliding airtight in its length, we will find that the contained air, or other gas, is compressed in front of the piston, as it is forced from one end toward the other of the base, and that this air, or gas, exerts a pressure which increases in ratio as the volume is diminished. This fact may be shown by inserting in the wall of the cylinder a tube containing an airtight piston, upon which bears a spiral spring holding it normally, as at *A;* the pressure there being supposedly equal on both sides of the piston, or equivalent to 15 pounds per square inch. If, now, the area of this small piston be exactly one square inch, and the spring of such a tension as to move upward through one of the spaces between the lines on the diagram behind the large cylin-

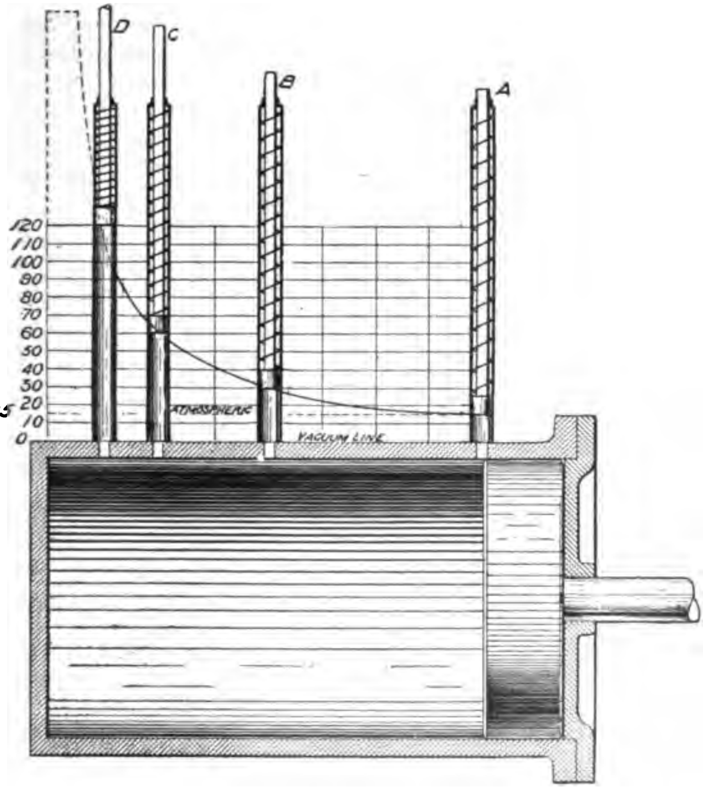


FIG. 384.—Diagrammatic Section of a Cylinder illustrating the compression and expansion of gases. This cylinder is filled with air at atmospheric pressure which represents a uniform 14.7 pounds to the square inch behind the piston, as shown by the position of the piston in the small cylinder, A. When the piston of the large cylinder is moved through half the length of the stroke, it shows 30 pounds pressure, as shown by the position of the piston in small cylinder, B; when at three-quarters stroke, 60 pounds, as shown by position of the piston, C; when at seven-eighths stroke, 120 pounds, as shown by position of piston, D. At full stroke it would be 240 pounds, the diagram behind the small piston giving the compression curve from 15 to 240.

der with each ten pounds of added pressure from below, the result will be as follows: When the piston of the large cylinder has been pushed through one-half its length, the depression of the spring in the smaller one will show that the pressure is just twice what it was at the start, or 30 pounds. At three-quarters the stroke it will show 60 pounds, and at seven-eighths, 120 pounds. If the four smaller cylinders be arranged in the wall of the cylinder, as in the accompanying diagram, the difference in pressure at these several points may be graphically represented. Then a curve, drawn so as to pass through the centre of each of the smaller pistons, will give an accurate average of pressure for every position of the large piston. On the other hand, as under the operative conditions in a steam-engine, it will represent the

FIG. 385.—A Typical Steam Engine Indicator. It consists of a cylinder, shown at the right, within which works a piston under tension of a helical spring of predetermined strength. The rod attached to the piston carries a pivoted arm which works on the horizontal lever, shown at the top of the cylinder. This lever carries a pencil bearing against the rotatable drum, shown at the left. This drum is so arranged with a spring that it may be rotated by the pull on the attached string. A sheet of paper is wound on the drum and held in place by the spring clips. The steam pressure in the cylinder acting on the spring enables the pencil to mark; the indicator card being traced by the rotative movement of the paper drum.

"curve of expansion," or the decrease in pressure from the moment of "cut-off," when the inlet valve is closed to the end of the stroke, when the exhaust valve is opened. If, therefore, steam be fed into the cylinder at 200 pounds pressure per square inch, and the inlet be closed when the piston has traversed one-eighth of the stroke, the pressure will stand at 100 pounds on quarter-stroke; at 50 pounds on half-stroke, and, at 25 pounds on the point of completed stroke, which shows that it is expanded four times.

The Steam Engine Indicator and Its Records.—The action of the small cylinders containing springs and pistons, as just explained, very well illustrates the operation of the steam indicator. With the simplest form of this instrument these cylinders are identical, except for a pencil carried on the uppermost end of the piston rod, and bearing upon a suitable tablet, which is moved backward and forward with the stroke of the steam piston. This is done by attaching the long arm of a reducing lever to the crosshead, and the shorter arm to a link-bar which holds the card, or tablet, to be inscribed. The several forms of the indicator most often used at the present day have a rotatable drum, which is attached by a cord to the short arm of the reducing lever, so as to be turned in one direction; being moved in the other direction by a contained spring, which rewinds the cord, so soon as the lever arm moves backward. Thus the records of a great number of strokes may be taken on one sheet of paper—wound about the drum and held on by clips—and there is no danger of interrupting the process.

The records thus made, by knowing the dimensions of the cylinder and the tension, or resisting strength, of the steam-actuated spring, may be very accurately calculated for the entire cycle of the engine.

The Temperature and Volume of Gases.—While it will be hardly necessary to go into minute details regarding the laws of gases, it will be well to briefly state the ascertained conditions by which the volume is increased while the pressure remains constant. Thus the "second law of gases," called Charles' or Gay Lussac's law, states that AT CONSTANT PRESSURE THE VOLUME OF A GAS VARIES WITH THE TEMPERATURE, THE INCREASE BE-

ING IN PROPORTION TO THE CHANGE OF TEMPERATURE AND THE VOLUME OF THE GAS AT ZERO. By actual experiment it has been ascertained that a gas increases on a ratio of 1-493d part of its volume at 32° Fahrenheit, with each additional degree added to its temperature. This places the "absolute zero," or the point at which a gas would assume its greatest possible density at — 461°, Fahrenheit, or — 273°, Centigrade. A higher degree of temperature within a closed receptacle, like a steam boiler, involves a higher degree of pressure there, and in the cylinder to which the steam is fed, because of the tendency to assume a greater proportional volume, although, because of the several inevitable sources of lost heat, no rule applies completely in the practical operation of the steam engine.

Determining the Temperature From the Pressure.—Tables showing the "properties of saturated steam," as far as regards the volume, temperature, pressure, etc., are given in many books, but the full determination of these points is a matter of some exactness of calculation. In order to explain the process for a given diagram, say like the one already found for a cylinder expanding 1-10 pound of steam from 120 pounds per square inch pressure to atmosphere, we can do no better than quote from Forney's "Catechism of the Locomotive." He says: "If the piston stand at the point shown in the previous figure, and 1-10 pound of water be put into the cylinder, and heat be applied to it, it would be necessary to heat the water to 212° before it would boil. To represent this heat, the vertical line, *JK*, is extended below the horizontal line, *AJ*. To heat 1-10 pound of water to 212° takes 21.2 units of heat,"—since one unit of heat is required to raise one pound of water at 39° Fahrenheit to one degree above—"which is laid off from *J* to *J'* to the scale represented by the horizontal lines. But, as is shown in the table in the appendix, after the water begins to boil, 96.6 more units of heat must be added to it to convert it all into steam of atmospheric pressure. This number of units of heat is, therefore, laid off from *J'* to *J''*. If the piston be moved to *E*, the middle of the cylinder, and 1-10 pound of water is again put into it, and it is all converted into steam, it will have a pressure of 30 pounds per square inch, as it occupies only half the volume that the same quantity of steam did before. To make water boil under a pressure of 30 pounds, it must be heated to a temperature of 250.4°, which in this case will require 25 units of heat, which is laid down from *E* to *E′*. To convert the water into steam, after it begins to boil, will require 93.9 more units of heat, which is also laid down from E′ to E″. In the same way the total heat to boil and convert 1-10 pound of water into steam at 60 and 120 pounds pressure, as shown in the appendix, is laid down on *C C″* and *B B″*, and the two curves, *B′ C′ E′ J′* and *B″ C″ E″ J″*, are drawn through the points which have been laid down. The vertical distance of the one curve from *A J* represents the heat units required to boil 1-10 pound of water at the pressures indicated by the curve in the previous figure, and the vertical distance of the second curve from *A J* represents the total units of heat required to convert 1-10 pound of water into steam of a volume indicated by the horizontal distance of any point of the curve from *A A″*, and when pressure is indicated by the expansion curve above. This curve and the heat diagram may be very conveniently combined by adding the latter below the vacuum line of the former. The relation of the volume pressure and total heat is thus shown very clearly."

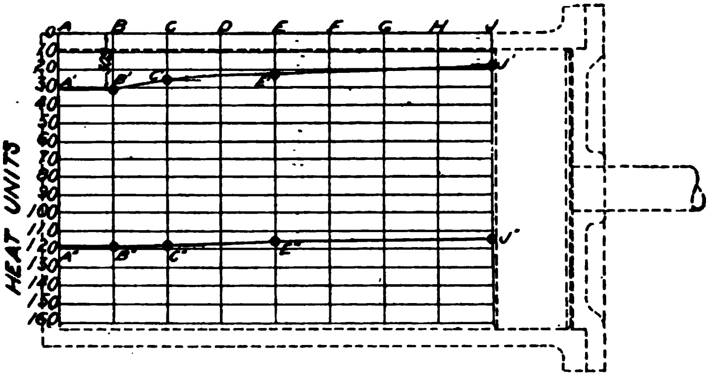


FIG. 386.—Diagram showing the number of heat units required to raise one-tenth pound of steam under the various pressures indicated by the position of the piston, at full stroke, half stroke and seven-eighths stroke. In using this diagram it is necessary to note that the heat units are calculated from —1° Fahrenheit, instead of from 39°, as is the general rule.

The Practical Effects of Steam Expansion.—A principle recognized as fundamental in steam engine practice is that the work-producing, or dynamic, property of a gas depends solely upon its temperature. This is, substantially, a statement of Joule's law, which compares the temperature of a gas, enabling it to exert a certain amount of power, to the stored energy represented in a body of a certain weight raised to a certain height above the ground. The body, in falling under the force of gravity, obtains a certain degree of acceleration, constantly increasing, by which the weight falling through the given distance is transformed into a force capable of producing a commensurate effect of impact on reaching the earth's surface. This potential energy of a substance, represented either by an acquired temperature or some analogous physical condition, which, under favorable circumstances, would enable the production of a definite amount of work, is known as "entropy." Could the whole power of a heated gas be realized in its expansion—which is to say, could its expansion be perfectly "adiabatic," or "isentropic," involving neither gain nor loss of heat in the process—we should have a theoretically perfect expansion curve on the practical steam engine. This is impossible, however, with the best arrangements yet contrived. Hence it is that the expansion curves of all engines fall far below what is demanded by theory from the original temperature and pressure of the steam, which involves that the final volume and the actual work accomplished are correspondingly diminished.

To quote from an authority on steam engines, "as we cannot take into consideration all the conditions which govern and modify the cycle of any motor, the usual practice is to calculate the power on the assumption that all theoretical conditions are complied with, and then modify the result by a certain coefficient of efficiency which practice has established for the particular type of motor under consideration."

The Indicator Diagram and the Engine Cycle.—The operative efficiency of an engine may be very well determined from the indicator diagram, which gives a pictorial representation of the internal conditions throughout the entire cycle of operations. As given by a noted authority, already quoted, the diagram tells us eleven different things essential to be known:

(1) It gives the *initial pressure*, or the pressure at beginning of the stroke. (2) It tells whether the pressure is increased or diminished during the period of admission. (3) It gives the point of cut-off, when the valve is closed and expansion begins. (4) It indicates the rate and pressure of expansion during the whole period of expansion. (5) It gives the "point of release," when the exhaust is opened. (6) It shows the rapidity of the exhaust. (7) It gives the degree of back-pressure on the piston, due to the exhaust having closed, preventing further expansion. (8) It shows the point of closing the exhaust. (9) It shows the *compression* of the residual steam in the clearance after closing the exhaust. (10) It gives the mean power used in driving the engine. (11) It indicates any leakage of valves or piston.

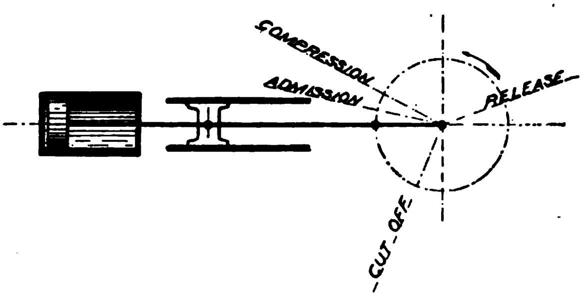


Fig. 887—Diagram of the Cycle of a Steam Engine. The dotted circle indicates the path of the crank; the arrow, the direction of rotation. The admission begins a little before the completion of the stroke; the cut-off is set somewhat less than quarter-stroke; release, or opening of the exhaust, at somewhat over half stroke; closing of the valve at the point marked "compression," after which the steam behind the piston is compressed in the clearance until the opening of the inlet valve.

The cycle of operations in a steam cylinder consists of four stages: (1) Admission; (2) expansion; (3) exhaust; (4) compression.

The indicator card (Fig. 232), which is drawn to illustrate the average conditions in an efficient low-pressure cylinder, shows the pressures at various points in the cycle. At line 1, the pressure of the steam in entering the cylinder is shown rising from a point of no pressure to 57 pounds, the curve in the vertical line indicating a back pressure of at least three pounds at the beginning of the admission, as shown by the fact that, at line 2, the pressure stands at 60 pounds, and, at line 3, just after the closure of the admission valve, at 58 pounds. The engine from which this diagram is taken has its cut-off at a point somewhat less than quarter stroke. After the point of cut-off, the pressure falls steadily, as indicated by the droop of the expansion line, until at ordinate, 10, it shows 13.75 pounds to the square inch. At this point the exhaust valve is opened and so continues during the return stroke, while the steam pressure is being exerted on the opposite face of the piston, until the pressure on that side of the piston is reduced to 3 pounds, absolute.

The second diagram, an actual tracing from the intermediate cylinder of a triple expansion engine, gives a good idea of the appearance of an average card for a double-acting cylinder. As will be seen, the figure is nearly duplicated in reversed position.

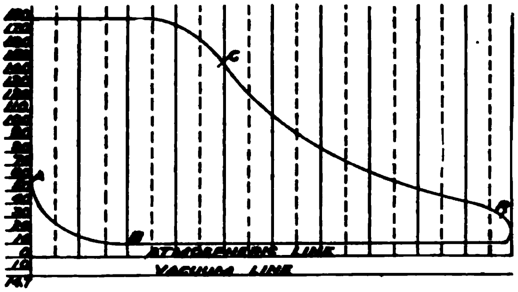


FIG. 388.—The Cycle of a Steam Engine, as shown by the Indicator Card. On this tracing, the admission is shown from A to C; the cut-off at C; the expansion curve from C to R; the release, or opening of the exhaust, at R, exhaust continuing from R to B; closing of the exhaust valve at B; compression of the residual steam in the cylinder clearance, from B to A. The figures on the left-hand vertical line indicate the gauge pressures. This diagram shows the operative conditions in a "high-pressure" cylinder; Fig. 232, in a "low-pressure" cylinder.

It would be identical if the cycular conditions were perfect, and if the valve were perfectly adjusted.

Reading an Indicator Diagram—The simplest method of reading a diagram is to rule equidistant lines from the vertical initial pressure line, so as to divide it into ten equal parts, or areas. Ordinates, indicated by the dotted lines, are then ruled between these, and given a value equivalent to the average of pressure represented by the lines on either side, as indicated by the point of contact with the admission line and the expansion curve. Thus in the single "low-pressure" diagram the three ordinates ruled on the admission line have each a value of 77 pounds, which represents 80 pounds less 3, back pressure. The fourth, touching the expansion curve at the point of 57 pounds, is marked 54 pounds; and so on to the tenth ordinate. The sum of the ordinates (449 pounds) divided by this number (10), gives 44.9 pounds per square inch as the *mean effective pressure* throughout the cycle, or the average of efficient pressure exerted on the piston, while the actual pressure is undergoing a steady fall from 77 pounds to 18 pounds, absolute. In similar fashion the diagram for both strokes is ruled off and estimated, the figures at the top of the figure indicating the cycle of pressure changes for the right-hand stroke, those at the bottom the cycle for the left-hand, or return, stroke.

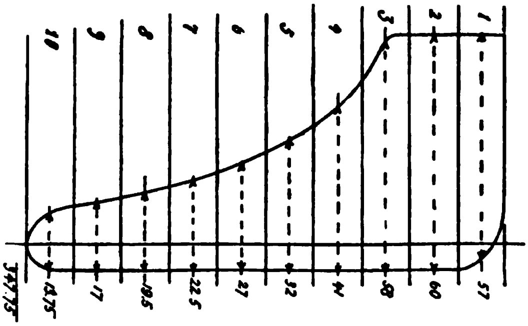


FIG. 389.—**Ideal Indicator Card for a low-pressure, or condensing, engine, showing the fall** of pressure below the atmospheric line. As shown in this cut, the effective steam pressures at the various points in the cycle vary between a maximum of 60 pounds and 13.75 pounds to the square inch before the opening of the exhaust. The sum of the ten figures for pressure is 347.75, which, divided by 10, gives 34.775, as the expression for the mean effective pressure. Because of the use of a condenser to reduce the back pressure, this figure represents the actual effective working pressure less 8 pounds, as indicated on the diagram.

Pressures and Temperatures of Steam.—In order that the steam-carriage driver may understand by a glance at the gauge what temperature is in his boiler, the following table of ordinary pressures is given:

Pressure.	Temperature.	Pressure.	Temperature.	Pressure.	Temperature.
15 lbs.	— 212° F.	55 lbs.	— 288° F.	100 lbs.	— 330° F.
20 lbs.	— 228° F.	60 lbs.	— 294° F.	105 lbs.	— 333° F.
25 lbs.	— 241° F.	65 lbs.	— 299° F.	120 lbs.	— 343° F.
30 lbs.	— 252° F.	70 lbs.	— 304° F.	135 lbs.	— 352° F.
35 lbs.	— 261° F.	75 lbs.	— 309° F.	150 lbs.	— 362° F.
40 lbs.	— 268° F.	80 lbs.	— 313° F.	165 lbs.	— 369° F.
45 lbs.	— 275° F.	85 lbs.	— 316° F.	180 lbs.	— 375° F.
50 lbs.	— 282° F.	90 lbs.	— 322° F.	195 lbs.	— 383° F.

Power Estimates from the Steam Consumption.—Referring to the tables on the properties of saturated steam, given in the appendix, we find a means of determining the power capacity of the engine from the diagram. Thus, taking the initial pressure in the cylinder, 77 pounds, we find it equivalent to a temperature of 309.3°, Fahrenheit ; taking the final pressure, 18 pounds, we find it equivalent to a temperature of 222.4°, Fahrenheit, and, the mean effective pressure, 44.9 pounds, to about 274°. This temperature represents about 1197.4 heat units per pound of water, which is equivalent to 924,392.8 foot-pounds; estimating 772 foot-pounds per thermal unit. Therefore, a cylinder, such as is mentioned in the quotation from Forney, which can contain one-tenth pound of steam per stroke at a mean pressure of, say 44.9 pounds, as per above diagram, will develop at 200 revolutions, or 400 strokes, per minute, a horse-power shown by the following formula:

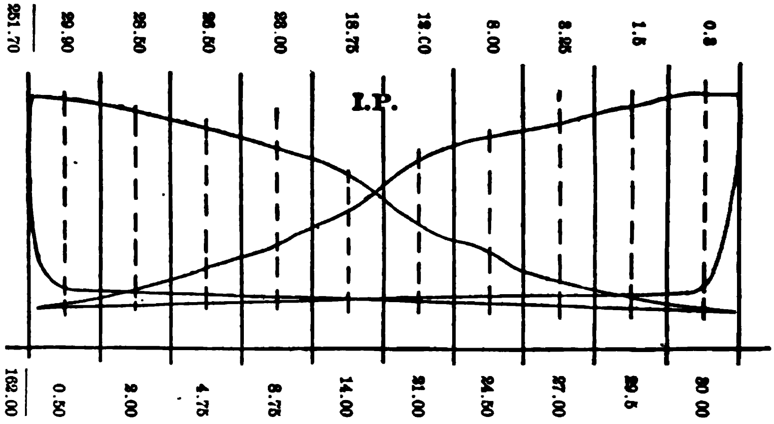


FIG. 390.—Card from the intermediate pressure cylinder of a triple expansion engine, with figures for pressure at the various points in the cycle. This is an average good diagram for a double-acting cylinder. The mean effective pressure is found, as follows: 151.70 + 162 — 313.70. Divide this by 20, we have 15.685 lbs. — M. E. P.

$$\frac{92439.28\times400}{33,000}=1120.48.$$

Elements in Estimates on Horse-Power.—As a moment's reflection will readily reveal, the elements entering into the estimate of an engine's horse-power are the effective temperature of the steam, as indicated by the mean pressure throughout the stroke; the content of the cylinder, as indicated by the length of the stroke and the area of the piston; and the number of revolutions per minute. The product found by multiplying these factors will give the number of foot-pounds made available; which expression, divided by 33,000, gives the indicated horse-power.

The denominator, 33,000, expresses the number of foot-pounds per minute in a horse-power. Thus, a horse-power is such a force as can lift a weight of one pound through 550 feet in each second, or, such as can lift a weight of 550 pounds through one foot in each second. This force constantly exerted through one minute, or sixty seconds, can lift 33,000 pounds through one foot, or one pound through 33,000 feet. Since, however, the action involves motion, it is cumulative in both time and space; requiring an increased area of operating surface, or an increased length of time, or both, to accomplish work in excess of the figures given. Thus, an engine exerting precisely one effective horse-power can raise 10 pounds through only 3,300 feet per minute; or 55 feet per second, and requires 10 minutes or 600 seconds, to raise 330,000 pounds through the vertical distance of one foot. To so enlarge the capacity of an engine that it can do ten times the indicated amount of work in a given space of time, or, so that it can do the indicated amount of work in one-tenth that given time, involves that the cubic content of its operating chamber, or cylinder, be proportionally increased, in order that ten times the amount of steam may be utilized in a given time, or for the accomplishment of a given work at each stroke of the piston. For it is evident that a mean effective pressure of 45 pounds per square inch means 90 pounds available pressure with a piston area of two square inches; 180 pounds available pressure with a piston area of four square inches, and 22.5 pounds available pressure with a piston area of 1-2 square inch.

First Rule for Calculating Horse-Power.—On the basis of these evident principles, two simple rules may be derived for calculating the indicated horse-power. This, however, is always in excess of the actual efficient horse-power, as will be subsequently explained. While there are numerous formulæ for determining this point, one of the most familiar is as follows:

(*a*) Find the area of the piston by multiplying the square of a radius in inches by 3.14159 (ratio between circumference and diameter).

(*b*) Find the pressure *in pounds* on the piston by multiplying the area by the mean pressure per square inch.

(*c*) Find the length *in feet* traveled by the piston per minute, by multiplying the length of the stroke *in feet*, or *fractions of a foot*, by twice the number of ascertained revolutions of the crank shaft per minute. This equals the number of strokes per minute for a double-acting cylinder.

(*d*) Find the foot-pounds available during the given space of time (one minute) by multiplying the pressure, *in pounds*, by the length traveled by the piston, *in feet*.

(*e*) Find the I. H. P. (indicated horse-power) by dividing this last product by 33,000.

The formula is: $\frac{\text{P L A N}}{33{,}000} = \text{I. H. P.};$

P being equivalent to the M.E.P. (mean effective pressure) in pounds per square inch.

L being equivalent to the length of the stroke in terms of feet.

A being equivalent to the area of the piston in square inches.

N being equivalent to the number of strokes of the piston, or twice the number of revolutions of the crank-shaft, per minute.

The element of speed, as expressed in terms of strokes, or revolutions, per minute, is important, and fundamental, in estimates on power, since, as must be evident from what has already been said, the superior power-capacity of one engine over another consists principally in being able to do, for example, ten times the work in a given time, or to do the same work ten times as fast. Therefore, an engine that can propel a given mass and weight of machinery at 300 revolutions of its crank-shaft and fly-wheel, per minute, is evidently three times more powerful than another engine which can move the same mass and weight of machinery at only 100 revolutions per minute. Consequently, in forming the expression for the horse-power ratio of any given engine, the other essential factors of the numerator are to be increased, as the number of times per minute the engine performs its complete cycle.

The Mean Effective Pressure.—The mean effective pressure (M.E.P.) may be calculated from the indicator diagram, as above explained, but it may also be found by knowing the initial steam pressure in the cylinder and the point of cut-off. Thus, as given in the table, entitled, "To find the M. E. P. of a Steam Engine," included in the appendix, we may take any initial pressure given in the first column, and follow the horizontal distance to the column corresponding to the number of times the steam is expanded. Thus if the initial pressure be 150 pounds, and the steam be expanded five times, we have a mean effective pressure of 78.30 pounds absolute, which, if the engine exhausts to atmosphere, must be diminished by 15, representing the back-pressure, giving 63.30.

To apply the formula given above to the calculation of an engine of, say, three inches piston diameter; four inches stroke; 63.3 mean effective pressure, and 200 revolutions per minute, we have:

$$\frac{63.3 \times .333 \times 7.0686 \times 400}{33,000} = 1.80 \text{ I. H. P.}$$

In this expression 63.3 represents the M.E.P. calculated as above; .333, the fractional expression in terms of one foot for four inches; 7.0686, the area of a circle whose diameter is three inches; and 400, the number of strokes per minute for a double acting cylinder at 200 revolutions of the crank-shaft. The result is, approximately, two horse-power, which, multiplied by 2 to represent the two cylinders, as in most steam carriage engines, gives an indicated horse-power of about four, which is fairly representative.

Second Rule for Calculating Horse-Power.—A second rule for computing the horse-power of a steam engine gives the product of:

(*a*) The square of the piston diameter.
(*b*) The length of the stroke in feet.
(*c*) The number of strokes per minute.
(*d*) The M. E. P. per square inch.
(*e*) The constant, .0000238.

Computing for the engine mentioned above, we have:

$$9 \times .333 \times 400 \times 63.3 \times .0000238 = 1.80+.$$

CHAPTER THIRTY-THREE.

CONSTRUCTION AND OPERATION OF A STEAM ENGINE.

The Slide Valves of a Steam Cylinder.—The mechanism by which steam is admitted to the cylinder of a steam engine, consists of a sliding valve of such a shape as to open communication from one end of the cylinder to the exhaust, while the other end of the cylinder is receiving steam direct from the steam chest. This will be readily understood from the accompanying illustration. There are two kinds of valves in common use on steam carriage engines; the common D-valve shown herewith, and the piston valve, as shown in a number of engines hereafter to be described. The object obtained by both valves is the same, although the piston valve is preferred by many engineers because it is better balanced in its operation, and also because, owing to its packing rings, it is less liable to leakage. However, with a well-made valve of either variety, the ends of economy and durability are equally maintained.

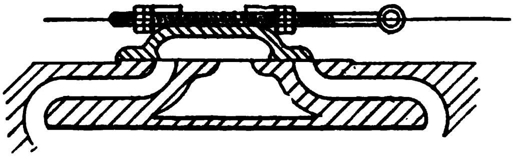


FIG. 391.—Slide Valve of a Steam Engine, showing position after cut-off of steam from right-hand end of cylinder, the exhaust continuing full from the left-hand end.

The Piston of a Steam Engine.—The piston of a steam engine, as shown in an accompanying figure, usually consists of a flattened cylindrical piece of slightly smaller diameter than the bore of the cylinder, in which it slides. Steam-tight contact is obtained by springing packing rings into grooves cut in its circumference. The accompanying cut shows three such rings sprung on the piston. The steam admitted through the inlet valve bears upon one face of the piston, and by its expansive energy causes the piston to move. As may be understood, however, from the fact that the piston rod is attached to one face of the piston, the bearing surface of the steam is decreased as the area of the rod. This item must be considered in exact calculations on engine horse-power, although for ordinary purposes it is negligible.

The Operation of the Slide Valve.—The valve controlling the inlet and exhaust ports of a steam cylinder is made of such length that, when in mid-position, it completely closes both inlet ports, neither admitting steam nor allowing it to be exhausted. In the valve shown on the accompanying sectional cut, it is evident that, supposing it to be moved either to the right or to the left, the communication will be opened with the exhaust port on the one side, sooner than with the steam chest on the other, thus permitting with a very slight variation in the length of the stroke, that the exhaust remain open even while the inlet of the steam to the opposite face of the piston is cut off. In calculating the operation of cylinder valves there are two important items to be considered—the "lap" and the "lead" of the valves. The "lead" of a valve is the amount by which the steam port is open when the piston is at the beginning of the stroke. According as this is more or less the inlet of steam is varied through the several fractions of the stroke. The lead may be changed either by cutting down the lap of the valve, or by varying the stroke length of the valve and its rod.

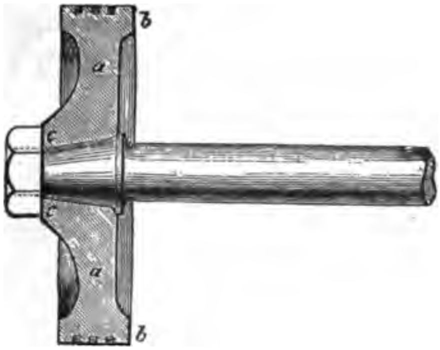


FIG. 392.—The Piston of a small double-acting steam engine, showing method of connecting the piston rod, and the position of the packing rings. The parts are: *a*, *a*, the body of the piston; *b*, *b*, the circumference bearing the packing rings; *c*, *c*, the central boss receiving the coned end of the rod.

The "lap" of a valve indicates any portion added to the length of the valve, so as to increase the portion of the stroke during which the ports are covered, beyond that length which is positively required to insure the closing of all ports when the valve is in mid-position. There are two kinds of "lap." The "outside lap" is any portion added to the length of the valve beyond that necessary to cover both inlet ports at mid-position. The "inside lap" is any portion added to the hollow or inside portion of the D-valve, over and above what is necessary in order to cover the inner edges of the steam ports, and to close the exhaust port from both sides when the valve is in mid-position.

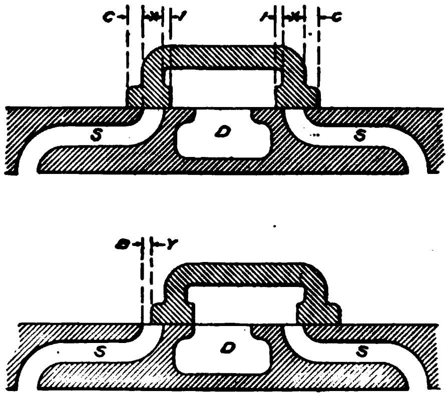


FIG. 393.—Diagrams illustrating the "Lap" and "Lead" of a Steam Cylinder Slide Valve. In both sections, S and S are the steam ports, and D the exhaust. The upper section illustrates the "laps" of a valve; the space between the lines C and X giving the "outside lap," and between the lines X and I the "inside lap." The lower section illustrates the "lead" of a valve; the space between lines B and Y showing the opening of the valve at the beginning of the right-hand stroke.

As already suggested in the previous chapter, the exhaust valve is closed somewhat before the completion of the stroke, thus allowing the residual steam in the clearance to be compressed somewhat before the opening of the inlet. The most important result obtained in this manner is that the compression produces a temperature, as near as possible, the same as that of the incoming steam, which is an efficient factor in heat economy, although producing some back pressure that slightly reduces the M. E. P. Another important consideration is that a soft cushion is thus provided for the forward-moving piston, which acts to save unnecessary wear on the crank and other moving parts, as is most essential in a small engine.

From the operations of this valve and cylinder, it must be evident that its stroke cannot be equal to that of the piston in the main cylinder. It cannot, therefore, be operated direct from the crank-shaft of the engine. Accordingly, the most usual method of operating the steam valves of an engine is by an eccentric on the main shaft, which operates the valve rod. This device may be either a single or double eccentric, according to the requirements, but when ready reversal of the engine's motion is desired, as in the case of a locomotive or marine engine, the double eccentric with the shifting, or Stephenson, link is most generally used.

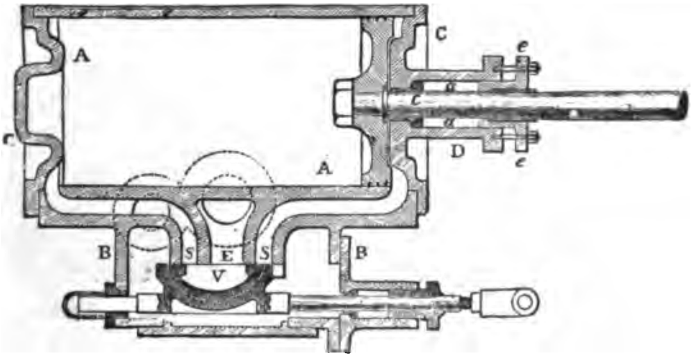


FIG. 894.—Section through a Steam Cylinder and Valve Chest, showing parts. A is the cylinder; B, the steam chest; C and C, the cylinder heads; D, the stuffing box; *a* and *a*, the packing gland; *c*, the piston rod; E, the exhaust port; S and S, the steam ports; V, the slide valve; *e*, *e*, the packing gland, held in place by screws in this engine.

The Eccentric Gear and Link Motion.—An eccentric is a circular piece of metal, a wheel in fact, except for the fact that instead of turning upon its centre, it is attached to the shaft at a point near its periphery. Around this disc-shaped piece is attached a circular metal strap, joined to a rod, which may be either attached direct to the valve rod, or, where two eccentrics are used, to one end of the swinging link. The link is an arc-shaped metal piece, usually made with a slot through the greater part of its length. It is hung from its centre point to a link-saddle, which, as shown in the accompanying figure, is bolted to either side of the slot and is suspended from the link-hanger either above or below. Within the slot is set a link-block, as it is called, so that it may slide in the slot through its entire length, whenever the link is raised or lowered on its hanger. To this link-block is attached the valve rod. The general arrangements of the link motion may be understood from the accompanying illustration.

The Operation of the Shifting Link.—As already stated, the link motion was originally intended only for reversing the engine, which is to say to enable the steam to be cut off from one side of the cylinder and admitted to the other, whenever desired, by shifting the motion of the slide-valve. In addition to this function, however, the link motion provides a means for using the steam expansively, when cutting off the supply of live steam at any earlier point in the piston stroke, which act is accomplished by reducing the travel of the slide-valve. When the link-block is at one end of the slot, the valve receives the motion of the eccentric rod attached to that end of the link, and, consequently, since the links are set at angles somewhat greater than 180 degrees, the one is for the forward motion of the en-

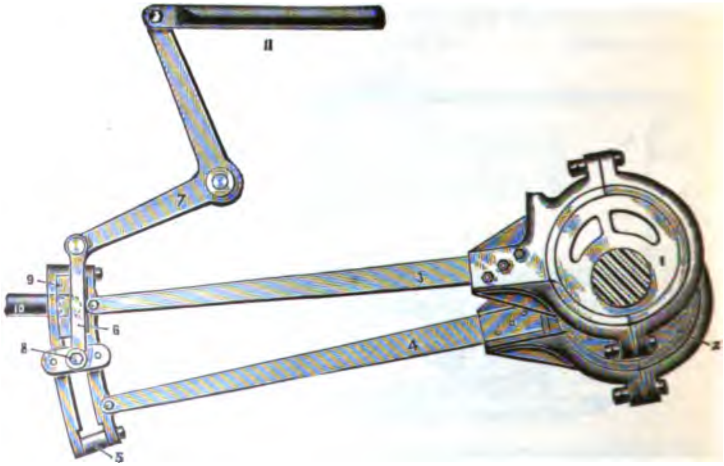


FIG. 395.—Diagram of the Link Motion and Eccentric Gear of a Steam Engine. The parts shown are: (1) backward eccentric; (2) forward eccentric; (3–4) eccentric rods; (5) slotted shifting link; (6) link hanger; (7) reversing arm; (8) link saddle pin; (9) link block; (10) valve stem; (11) reach rod. The position shown in the cut indicates that the backward eccentric is in gear which gives a reverse motion to the engine.

gine, the other for the reversed motion. In the accompanying illustration, the backward eccentric is in gear. By this means, whenever the link is shifted, only the eccentric whose rod stands opposite the link-block imparts its motion to the valve. The other is practically inactive, except for imparting a slight oscillatory motion to the link, which in general practice is negligible. The link which is in gear acts, in reality, like a short-throw crank, or as if it were a single eccentric. From the position of "full-gear"—that is, when the link-block stands at either end of the slot—the travel of the valve may be more or less modified until the centre point of the slot is reached, which point is called mid-gear. There the travel in either direction is so slight that the steam and exhaust ports of the cylinder are not opened. This is in reality the "dead point," and further shifting of the link in the same direction begins the process of reversing by increasing the travel of the valve in the opposite direction. When at mid-gear the valve partakes of the motion of both eccentrics equally, but since their motion describes a cassinian, or flattened figure 8, laid on its side, of which the link-block is the centre, the motion is at its point. Although this general movement is continued so long as the engine is in operation, it is reduced to practical zero at the link-block set at full gear.

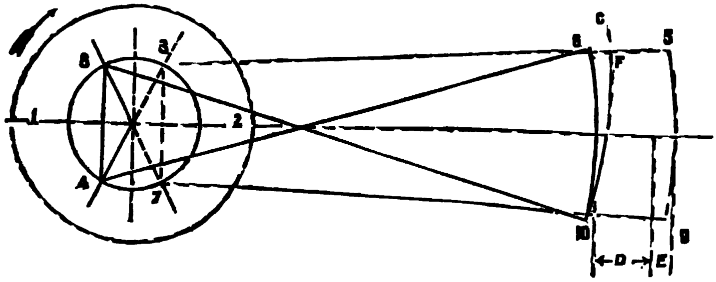


FIG. 896.—Diagram of the Operation of the Link Motion. The centres of the two eccentrics being at 4 and 8, the crank pin at 2, the link at mid-gear, the eccentric rods will be indicated by the full lines, 4-6, 8-10. When the crank pin is at 1, the centres of the eccentrics will be at 3 and 7, and the positions of the rods on the dotted lines, 8-5 and 7-9. The distance, D, indicates the vertical distance between the centres of the eccentrics in the full and dotted-line positions. If from the centre, 8, with the rod as the radius, an arc be drawn to F, the distance, C, shows the position of the link if both rods were "open" with the crank at the cylinder end, 2, instead of at the opposite dead centre, 1. The distance, C, is equal to the distance, E, and the total distance (D + E) that the valve moves is twice the lap, plus twice the lead, plus the distance, or angularity, occasioned by the rods being crossed, when the crank is on the cylinder end dead centre, 2, becoming opened when the crank is at dead centre, 1.

When the link is at full gear, the travel of the valve is equal to twice the throw of the eccentric, less the angularity of the eccentric rod. When the link is at mid-gear, the travel of the valve is equal to twice the lap and lead of the valve, plus twice the angularity of the eccentric rods. By the angularity of the eccentric rods is meant the distance the centre of the link or the valve would move, should the rod of the geared eccentric be disconnected from it and connected with the other link. The amount of the angularity thus, of course, varies with the length of the rods. The shorter the rods, the greater the travel of the

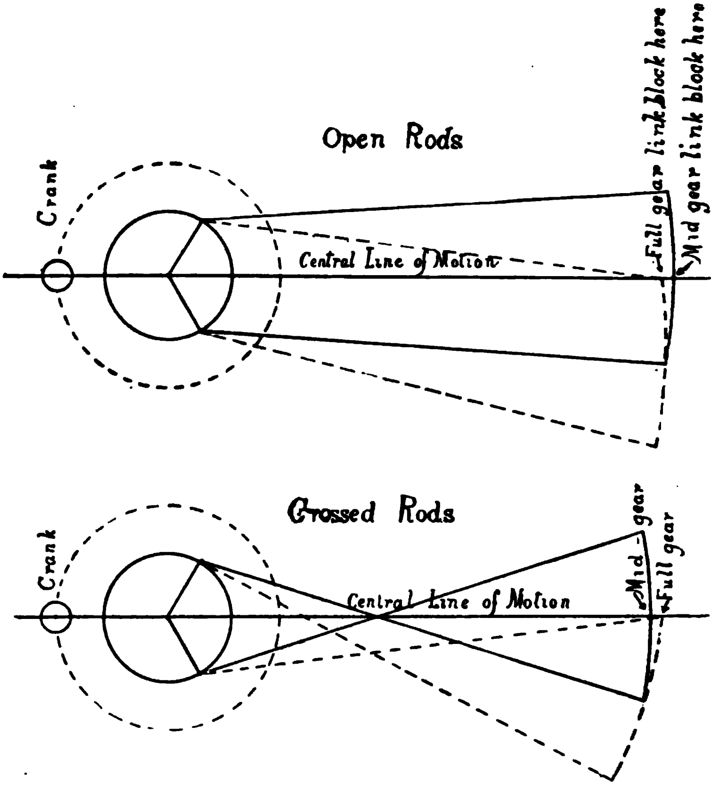


FIG. 397.—Diagram showing the positions of the eccentric throws and rods at full gear and mid-gear, when the rods are "open" and "crossed" with the crank at the forward dead centre, marked 1 in the previous cut.

valve, owing to the crossing of the rods during a one-half revolution of the crank. When the eccentric rods of a direct connected link motion are disposed as shown in the accompanying diagram, and the link motion and gear of the crank is at the dead point marked 1, the rods are said to be open. If they are disposed as shown by the dotted lines in the same figure, and the crank is at the dead point, 2, they are said to be crossed. There is, however, an important difference in the operation involved in the relative positions of the rods to the crank, as shown by the travel of the steam valve, since rods which are open at the specified point give an increasing lead from full-gear towards mid-gear, while rods crossed at that point give a decreasing lead in the same direction. Variation of lead from full-gear to mid-gear is due to the curvature of the link-arc, and for a link of short radius is more pronounced than for a link of longer radius. As a general rule, the radius of the link is equal to the length of the eccentric rod.

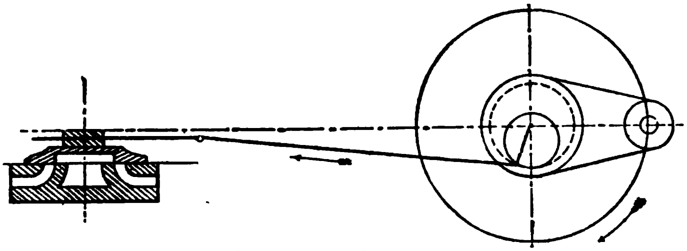


FIG. 398.—Diagram with a single eccentric, illustrating the position of the steam valve, when the crank pin is at the forward dead centre, the throw of the eccentric being at an angle off the perpendicular. The arrows show the direction of motion.

The Practical Expansion Ratio for Steam.—In the practical operation of the steam engine, as most generally understood, the steam is fed direct from the boiler to the cylinder, there expanding from its original pressure to a number of volumes, proportioned to the length of the stroke and point of cut-off. The idea of cutting off the supply of steam before the completion of the stroke, and making use of its expansive energy during the remaining portion, constitutes, as we have seen, the first improvement made by Watt. According to Boyle's Law, already quoted, the pressure of the steam is in exactly inverse ratio to its expansion, which is to say that when a body of steam is expanded to twice its original volume, it should have just one-half its original pressure, so long as the temperature be constant. This law is never exactly followed in practice, the general rule, as shown by indicator diagrams, being a rapid fall during the first period of expansion and a more gradual one in the latter period. However, for general purposes, the law is assumed to be perfectly operative, and the rule for calculating the pressure at any point of expansion, is to divide the original absolute pressure by the number of times it has expanded. Thus, steam fed to a cylinder at 100 pounds gauge, or 115 pounds absolute, has a pressure of $57\frac{1}{2}$ pounds when expanded to two volumes, a pressure of 38 1-3 pounds when expanded to three volumes and a pressure of $28\frac{3}{4}$ pounds when expanded to four volumes. It would, therefore, require as many expansions to reduce the gauge pressure of 100 pounds to atmosphere, as 15 is contained in 115, which is 7 2-3 times. If the flow of steam to the cylinder be cut off at one-half stroke, it has been ascertained by numerous experiments, that its efficiency will be increased 1 1-7

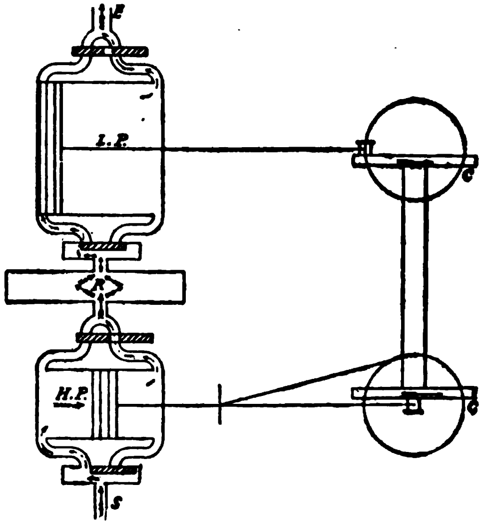


FIG. 399.—Diagram of a "Cross Compound" Steam Engine. The cranks, C and C, are at 90°. The high-pressure steam port is at S; the H. P. exhaust to L. P. cylinder at R, and the exhaust to atmosphere from the low-pressure cylinder, at E.

times what it would have been if the steam at the same point has been released into atmosphere. The following table gives the efficiency of steam cut off at various other points of the stroke:

Cutting	off at	$\frac{1}{10}$	stroke	increases	efficiency	3.3	times.
"	"	$\frac{1}{8}$	"	"	"	3.0	"
"	"	$\frac{2}{10}$	"	"	"	2.6	"
"	"	$\frac{1}{4}$	"	"	"	2.39	"
"	"	$\frac{3}{10}$	"	"	"	2.2	"
"	"	$\frac{3}{8}$	"	"	"	1.98	"
"	"	$\frac{4}{10}$	"	"	"	1.82	"
"	"	$\frac{1}{2}$	"	"	"	1.69	"
"	"	$\frac{6}{10}$	"	"	"	1.50	"
"	"	$\frac{5}{8}$	"	"	"	1.47	"
"	"	$\frac{7}{10}$	"	"	"	1.35	"
"	"	$\frac{3}{4}$	"	"	"	1.28	"

These figures give a general idea of the economy gained by the practice of cutting off the steam at various points of the stroke, but, as is evident, the end of economy is obtained by altering the final pressure in the cylinder, and, consequently, also the mean effective pressure throughout the entire cycle. If, therefore, we wish to utilize the full power of any given boiler pressure, the end of combined economy and high efficiency is far better attained by the operation known as compounding.

Limits of Varying the Valve Motion by the Link.—On the question of the practical limits of varying the cut-off of the valve, by varying the motion on the link, authorities seem to vary in regard to the steam engines used on carriages. Several manufacturers, however, use a notched quadrant for enabling the driver to shift the link, as desired, and with apparently good results, in spite of the oft-repeated claim that the engine of a steam carriage is too small to allow of a very wide variation in this respect. On the authority of one or two practical steam-carriage drivers, whose opinions have appeared in print, it may be stated that some advantage in point of steam economy has been achieved by varying the cut-off from, say, seven-eighths to one-half stroke on a level roadway. The majority opinion has it, however, that, although some saving may be achieved in this direction, proper care and management of the motor and parts attain the end far more effectively: since the strain on the driving mechanism incident to shifting the link increases wear and tear in an even greater proportion than the gain in steam saving. In short, the situation seems to be that a small steam motor requires a fly wheel to compensate for the jar resulting from frequent shifting of the steam inlet.

On Compounding a Steam Engine.—A compound engine is one in which the steam is used several times over in as many separate cylinders, although usually applied to engines operating with two cylinders. The steam is fed from the boiler direct to the first cylinder, in which it is cut off late in stroke, in order that its pressure may be utilized to the greatest possible extent The exhaust from this cylinder is then fed into the second cylinder, generally two or three times the cubic contents of the first, and is worked expansively to a point as near atmospheric pressure as possible. The most practical and efficient application of this principle is in the triple and quadruple expansion engines, so largely used in marine work, which, in connection with the vacuum-producing condenser, allows the steam to be worked from the highest available pressure down to practical zero. There are two common forms of compound engines of two or three cylinders, which from the arrangements of the working parts, are known as "tandem-compound" and cross-compound." In the tandem-compound engine, the cylinders are placed end to end, the several pistons operating one piston rod. In the cross-compound engine the cylinders are placed side by side, the two or more piston rods operating on a single crank-shaft. The latter model is that most frequently used in compounding steam engines for motor vehicles.

CHAPTER THIRTY-FOUR.

SMALL SHELL AND FLUE BOILERS FOR STEAM CARRIAGES.

Small Shell Boilers for Carriages.—Many of the best known makes of American steam carriage have vertical fire-tube shell boilers, usually placed beneath the seat. All such boilers are of small dimensions, frequently little over one foot in either diameter or height, with a consequently small water capacity. But they have a very extensive heating surface, owing to the insertion of a large number of fire flues, and, according to many showings, seem capable of generating a power pressure far in excess of the usual rule of proportions for surface. The shells of such small boilers are usually of steel, sheet-riveted or cold drawn piping, with a thickness ranging between three-sixteenths inch (as given for the Marlboro and Victor steam carriages) and five-sixteenths inch (as given for the Foster steam wagon). Such boilers admit a working pressure of between 150 and 180 pounds to the square inch, with blow-off pressure between 225 and 320 pounds, several of them claiming to have withstood tests of more than three times their blow-off pressure. The flues of such small boilers, which are generally of copper, about one-half inch in diameter and 16 B. W. G., or .065 inch thick, are expanded into the tube plates at either end, the joints being secured as strongly as possible.

Heating Surface of Small Boilers.—The immense heating surface afforded by using a large number of such flues in a boiler of moderate dimensions may be illustrated by the following figures:

In the ordinary two and four-seat carriages made by the Locomobile Company of America a boiler is used whose dimensions are 14 x 14 inches, with 298 half-inch copper tubes.

Computing for the area of a circle of 14-inch diameter we find it to represent 153.94 square inches, which gives 307.88 square inches as the surface of both tube plates.

Computing for the cylindrical surface of the shell, we find the circumference to be the product of 14 (diameter) and 3.14159 (ratio between circumference and diameter of a circle), giving 43.9822 inches as the circumferential measure, which, multiplied by 14 (length of shell), gives 615.7506 square inches, or a total surface for the boiler shell of 923.63 square inches, or 6.39 square feet.

With the flue-tubes we may calculate in similar fashion. Thus the inside diameter of each tube is approximately one-half inch, exactly .437 inch. To find the inside circumference, we multiply .437 by 3.14159, which gives us, in full, 1.37287483. Multiplying this by 14, to find the area of each tube, we have 19.22024762 square inches, which multiplied by 298 (total number of tubes) gives us 5728.633 square inches, or 39.782 square feet, as the heating surface represented by the flues, over six and one-half times the total outside surface of the boiler shell. If to this figure we add 307.88 square inches, or 2.13 square feet, the surface area of the two tube plates, we have 41.91 square feet, as the total heating surface of the boiler.

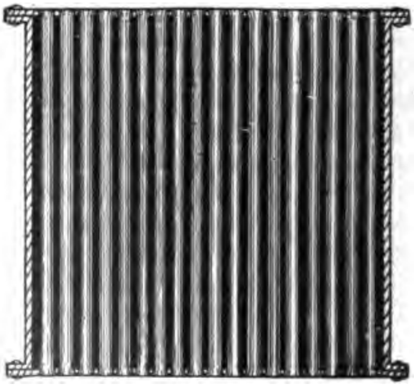


Fig. 400.—Copper Shell and Flue Boiler, with flange connections for the tube plates, as used on the "Locomobile" and other American steam carriages. The shell is strengthened by winding several layers of steel piano wire around the length of the boiler. This cut gives a section on the centre, showing one row of flues.

According to the rule given above, a boiler of such dimensions should be able to drive an engine of about three-horse power. But it has been claimed that this make of boiler has developed over four-horse power, which fact is probably due to rapid steam generation under fire from a powerful burner, and also the efficiency of the engine used. Similarly excellent results have been achieved with other makes of fire flue vehicle boilers, a fact which amply justifies the course followed by most American carriage builders, of adopting a steam generator of familiar pattern and increasing its efficiency along concurrent lines, instead of spending time and energy in the effort to produce an instrument, which should embody the requirements of perfection.

FIG. 401.—Small Carriage Boiler made from a seamless steel pressing, the lower tube plate being flanged over and riveted in, as indicated at the base of the figure, this being the only seam in the structure.

The Flues of Small Boilers.—Several carriage builders still cling to the practice of using steel tubes in their boilers, thinking by this means to supply an additional assurance against explosion. The custom is growing, however, of using cold drawn copper tubes for this purpose, and experience seems to warrant the statement that boilers containing them are quite as durable as those constructed of steel throughout. Copper is superior to steel in boiler construction from the fact that it has a much higher thermal conductivity, involving considerably smaller loss of heat in proportion to its exposed surface; also from the fact that it more easily resists the chemical action of impure water, in point of preventing both corrosion and the deposit of incrustations, and is less liable to oxidation from the action of heat. On the other hand, it is inferior to steel in the fact that its tensile strength is greatly reduced under increasing temperatures. As quoted by several boiler authorities, its diminution of strength increases from .0926 as compared to steel at 270 degrees, Fahrenheit, to .2133 at 460 degrees, .2558 at 532 degrees and .3425 at 660 degrees. Well-made copper tubes, however, can readily withstand a constant working pressure of between 150 and 180 pounds to the square inch, which figures represent the average used in small vehicle boilers. These advantages in copper, both pure and in alloy, led long since to the use of brass tubes in some locomotive and other large boilers, with the best results. For this purpose brass proved far superior to iron, or steel, in resisting the abrading action of small particles of coke or coal drawn through the draught; in having a greater power of springing under increased expansion, and of being less liable to break. On the other hand, if we may deduce a principle from practical

FIG. 402.—Bottom View of a Type of Boiler shown in Fig. 145, exhibiting the method of riveting in the lower tube plate.

experience on this point, the inferior strength of copper tubes for boilers is a positive advantage, for, since they are more liable to collapse under stress of over-heat and expansion, the effect may be similar to that found in water-tube boilers under similar conditions—the bursting of one or two tubes instead of a disastrous rending of the outer shell. This seems to be the experience in some cases. A prominent steam carriage concern says of its tubular boiler: "If the boiler should accidentally be allowed to run dry and become overheated, all that has ever been known to happen is that the tubes collapsed at the ends and the boiler leaked. The water and steam escaping gradually reduce the pressure until none is left—the result of which is that the tubes (a number of them) are ruined and must be replaced."

FIG. 403.—Another type of Small Carriage Boiler, showing both tube plates inflanged and riveted to a seamless steel tube.

On the matter of metal and metal combinations suitable for use in boilers, the following is quoted from an excellent article on the subject:

"The question of the strength of materials for boilers was elaborately tested some years ago by the Franklin Institute. It was then found that the tenacity of boiler plate increased with the temperature up to 550 deg. Fahr., at about which point the tenacity began to diminish as the temperature rose. At 32 deg. Fahr. the cohesive force of a square inch section was 56,000 lbs.; at 570 deg. it was 66,500 lbs.; at 720 deg. it was 55,000 lbs.; at 1,050 deg. 32,000 lbs.; at 1,240 deg. 22,000, and at 1,317 deg. 9,000 lbs. Copper follows a different law and appears to be diminished in strength for any increase in temperature. At 32 deg. Fahr. the cohesion of copper was found to be 32,800 lbs. per square inch section, and exceeds this cohesive force at any higher temperature, the indications being that the square of the diminishing strength keeps pace with the cube of the increased temperature. Strips of iron cut in the direction of fiber were found to be 6 per cent. stronger than when cut across the grain. Welding was found to increase the tenacity of the iron, but welding together different kinds of iron was not found to be favorable. Overheating was found to reduce the ultimate strength of plates from 65,000 to 45,000 lbs. per given section, and riveting of plates was found to diminish the strength one-third."

Steam Feeding Apparatus.—In general, one of the gravest difficulties experienced in small boilers with a large number of fire flues and consequently small clearance, or water space between them, is the danger of priming. This danger assumes graver proportions when we consider the small cubic content of the cylinders, which would speedily operate to disable the engine, were it not that some means were adopted to insure the delivery of perfectly dry steam. This end is achieved by some boiler-makers by the use of a *baffle plate,* a metal sheet of slightly smaller diameter than the boiler, which is fixed above the water level and somewhat below the upper tube plate, so that the small clearance all around will permit the steam to rise and emerge through the steam pipe fixed in the upper plate, while at the same time effectually confining the water circulation to the space below it. Such a device is particularly efficient when used in connection with a *separator,* or pipe of large diameter running across the diameter of the top plate, connection being made with the steam space at the centre of the plate and, with the feed pipe to the engine, by another pipe contained within the separator and having a number of small holes drilled in its length. In this contrivance an extra precaution is found against the escape of unvaporized water. Any form of separator may be utilized for this purpose. A device of somewhat similar description is used in the Stanley carriage boilers as an "internal dry pipe," being inserted in the length of the boiler, closed at the lower end and having the entrance very little below the top tube plate. The steam feed pipe, also closed up at the bottom and having a large number of small holes in its length, is enclosed within the first pipe and emerges near the top of the shell. Other manufacturers claim that the end of securing dry steam feed is insured by maintaining the water level at a point about midway in the water chamber, thus allowing space for extra expansion, but it is probable that the majority also employ either the baffle plate, the internal dry tube, or some contrivances of their own to add extra assurance of the result.

CHAPTER THIRTY-FIVE.

OF WATER-TUBE BOILERS, AND THEIR USE IN STEAM CARRIAGES.

Of Tubular Boilers in General.—The wide use of tubular boilers in steam carriages and for other purposes is explained by the fact that in its use the problem of how best to control the circulation, to the ends of quick steaming and higher durability, through more uniform distribution of heat, has been best solved. Although very many varieties of tubular boiler possess high efficiency as generators of steam, none of them attain such great power for absorbing heat but what there is still room for efforts to discover some means of neutralizing waste in this particular.

Advantages of Controlling Circulation.—Furthermore, by suitable arrangements for directing the rising and falling currents, so that interference is obviated, another very desirable end is attained—chemical impurities, held in solution by the water, and precipitated, so as to form scale deposits, when it is evaporated, are prevented from locating and hardening; being received into mud drums suitably arranged at the lowest point of the water chamber, where they can be conveniently removed. According to statistics furnished by various authorities these scale deposits, consisting mostly of lime and other non-conducting substances, interfere with the heat-conducting properties of the metal to an enormous extent: A deposit of 1-16 inch involving a loss of 13 per cent. of the fuel; a deposit of ⅛ inch, a loss of 25 per cent.; a deposit of ¼ inch, a loss of 38 per cent.; a deposit of ½ inch, a loss of 60 per cent. The result of allowing such incrustations to increase will be inevitably that the metal surface exposed to the fire is burned out and the boiler ruined.

Advantages of Water-Tube Boilers.—With the water-tube boiler, on the other hand, the fact that the full force of the steam pressure cannot bear on any one extended surface involves that in the event of overheating or sinking of the water level, only one or two of the tubes will burst with no very serious consequences. Wellington P. Kidder, a boiler expert, enumerates the following ten points of structural advantage in a well-made water-tube boiler, adapted for road wagons:*

(1) The water should not be expelled by heat from the tubes nearest the fire; (2) foaming and priming are no more likely than in shell boilers; (3) there need be no joints near the fire; (4) there may be but few parts, easily and cheaply assembled; (5) the weight is about two-thirds that of a shell boilėr of equal capacity; (6) being in sections, it may be easily taken apart for cleaning or repairs; (7) an easily removable casing will deflect downward any escape of steam or water, due to breakage of tubes; (8) a natural and rapid circulation through all tubes insured; (9) ample provision for insuring dry steam for the cylinders; (10) the ready possibility of blowing steam through the tubes for removing incrustations, also, between them, for removing soot. In a compliance with such conditions in construction

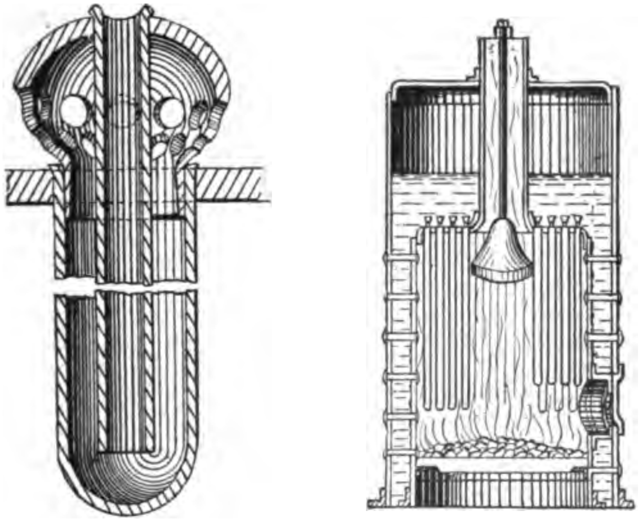


Fig. 404. Fig. 405.

Figs. 404, 405.—Field Water-tube Boiler and one of the Field Tubes, showing inner tube and method of controlling circulation. A number of such tubes are hung over the fire-box of the boiler, as shown.

he finds the following eight points of superiority: (1) All danger minimized; (2) steam quickly generated; (3) weight minimized; (4) superior absorption of heat by inclined tubes; (5) more heating surface found on exterior of tubes; (6) less opportunity for dust accumulation; (7) higher working pressure of steam practicable; (8) better elastic provision for expansion. He confesses, however, that most of the really practical water-tube boilers for vehicles present some one or all of the following three disadvantages: (1) Too much bulk and complication; (2) liability to foaming and priming; (3) danger of expulsion of wafer from the tubes nearest the fire by overheating. The last-named fault, if not the others also, is to a large extent offset in the De Dion, Weidnecht and Clarkson-Capel water-tube generators by the lower chamber or water-jacket; and in the Lifu generator by the trunk tube and water arch features. The Lifu generator is nearly the most elaborate attempt yet made to mechanically control the water circulation. In the ideal water-tube boiler, however, the tubes would run across the draught through a portion of their length, at least, thus making possible a greater absorption of heat, through the breaking of the air currents. This result is immensely increased when the successive rows of tubes are staggered, so as to still further divide up the draught currents.

The Field Finger-Tube Boiler.—A type of water-tube boiler, which has given good service in several steam carriages, notably the Thomson-Ransome coach, built about 1870, and the Velee coach, built about 1880, is of the ordinary fire-engine upright pattern, with a central smoke flue controlled by the form of baffle damper, for regulating the heat currents, shown in the accompanying figure. Instead of five tubes or coils, it has the bottom crown plate fitted with a number of suspended "finger tubes," through which, on account of the peculiar shape of the movable baffle damper, the heated gases are forced to circulate. Each of these tubes, which is closed and rounded off at the bottom end, like a chemist's test tube, is inserted and expanded in an aperture in the crown sheet. In this inner open end, as shown, is inserted a second smaller tube, which, in turn, depends from a perforated globe, or a suitable collar, the three elements being firmly attached. In the style of Field tube shown in the figure, the perforated globe carries a tapering ferrule that is driven into the end of the outwardly hanging finger tube, thus further securing the joint.

The operation is to be understood readily: The water in the lowest level of the finger tubes is directly affected by the heat of the furnace, and rises along the sides; the descending strata, working down to take the place left by the rising mass, moves through the orifice at the top of the globe and down the central tube. The circulation is thus perfectly guided and, all interference of the rising and falling currents being prevented, the greatest possible percentage of heat is utilized. In spite of the high efficiency of Field tube boilers, they have been almost entirely supplanted in the domain of motor vehicles by other types less difficult to construct and maintain.

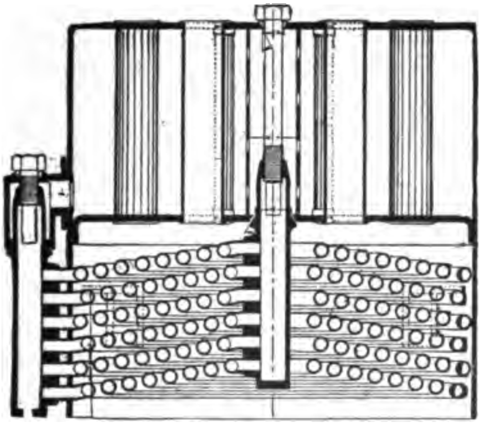


Fig. 406.—The Geneva Carriage Boiler. This boiler consists of several coils of tubing connected at inner and outer extremities to headers, as shown. The water and steam chamber above is constructed like an ordinary flue boiler.

The Geneva Tubular Boiler.—Experience seems to prove that those manufacturers who do not use the familiar flue boiler have some form of multiple coil generator, such as are about to be described. Two of the best designed among the coil boilers are the Geneva and the Toledo, named respectively as the carriages they propel. The Geneva boiler has the general characteristics of water-tube boilers, but has been well described as a "combination of tube and flue boilers." It consists of six somewhat conical superposed coils of ⅝ inch seamless cold-drawn steel tubing, each 17 feet total length, which are pinned and brazed to a header, or manifold tube, both at the centre of the coils and at the outside extremity. These two "headers" serve the same ends as do the head plates of the generator just described; being simply common chambers in which the water may pass from one coil to another, as impelled by the tendency of circulation. Thus the tendency within the inner header is from the lower to the higher coils and within the outer, the reverse. By this means the circulation is directed into its natural channels. and, at the same time, the water within the coils is exposed to the greatest possible area of heat. The heat is also largely economized, as in most tubular generators, by staggering the rows of tubes, thus repeatedly deflecting and breaking up the current of burning gas, as it moves upward to the vent. The water intake is at the base of the outer header tube, and the feed water, as it enters, is urged into the coils by the pressure of the circulating liquid; its temperature being immediately raised by contact with the heated tubes. Both headers are secured by bolts to the drum above the tiers of coils, as shown, and open into it by ports that permit the steam to be given off, and any water escaping to follow the general direction of circulation. This drum is, in fact, a flue shell boiler, being pierced by 16 flues of 1¾ inch diameter, which enable the super-heating of the steam, as the products of combustion pass through them.

The Geneva boiler is 8 inches high, measured from the base to the apex of the coned coils, and the water chamber measures 9 inches from the crown plate, giving a total height of 17 inches. It is also 17 inches in diameter. The engine which it supplies is rated at 6 horse-power, gross, which represents an excellent average of output for its 29 1-3 square feet of heating surface being, in fact, 1 horse-power at the boiler for each 5 square feet.

The Toledo Water-Tube Boiler.—The Toledo boiler, although differing considerably in some particulars, is constructed on the same general principles as the Geneva. It consists of an annular water and steam chamber, formed by bolting together two seamless steel shells, suitably shaped, as shown, within which eight slightly coned coils of ⅝ inch steel tubing are attached at top and bottom. The outer connection of each of these coils is near the bottom of the annular space, instead of in a header of any description and the centre connection is near the top of the chamber. The attachments of all the coils, both at the top and at the bottom, being on horizontal planes, perfect circulation is made possible from the lowest point of heat contact upward. Because of the excellent character of these circulation guides, dry steam is fed to the engine, without danger of priming, the annular steam space serving as a centrifugal separator. The dimensions are 19 by 19 inches, but 1½ inches of asbestos packing gives a total breadth of 22 inches. A heating surface of 38 square feet is reckoned, on which is claimed 1 horse-power for every 5 feet, giving a total of 7½ horse-power at the boiler.

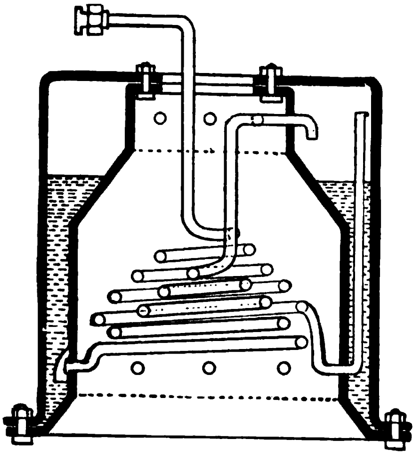


FIG. 407.—Sectional Elevation of the Morgan Boiler, formerly used on the Toledo Carriage. The disposition of the coils may be understood from these cuts, also the steam connections through the superheating coil. The sectional view shows the steam superheating and one of the generating coils in position, with connections indicated for other coils. As shown, the steam enters a vertical tube somewhat below the top of the steam space; thence flowing downward, through one of the coils above the fire and out to the engine through the feed pipe.

Since the two seamless shells, forming the annular water and steam space, are bolted together—no rivets are used—they may be readily taken apart for necessary repairs or cleaning. The coils, also, being connected to the shells by joints of special pattern, may be removed with ease.

Heavy Vehicle Boilers.—The achievements noted in the early days of the Nineteenth Century, in producing generators capable of operating their somewhat unwieldy coaches, has been more than outdone in the present day. Perhaps among these heavy-vehicle generators none have proved more efficient than the Thornycroft, whose details are shown in several accompanying diagrams. Briefly, it consists of two annular chambers, one above, one below, connected together by 168 slightly inclined tubes, set four deep in the tube plates and staggered, as shown.

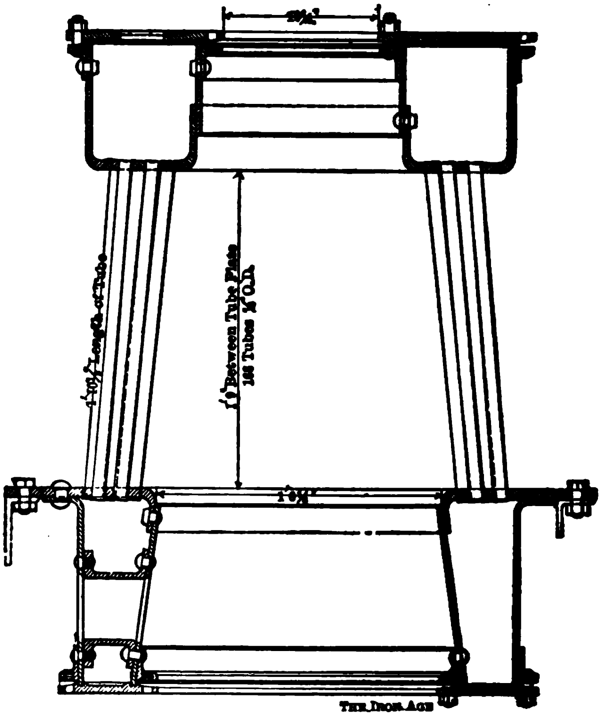


FIG. 408.—The Thornycroft Steam Wagon Boiler.

Both tube plates are steel pressings, and the upper and lower chambers are built up on them by ring-shaped sections, suitably riveted. But the top and bottom plates of the boiler are bolted on, as shown, so as to admit of their ready removal for cleaning or repairs. Fuel, usually coke, is fed to the fire through the aperture in the top of the boiler, and, since the grate is situated at a point about the bottom of the cut, the fire is confined below the water tubes, touching no part of the generator except the inwardly-sloping sides of the lower drum. Access to the fire, for the removal of clinkers, may be had through the door shown in the lower drum at about the level of the grate.

The entire structure is sheathed by a suitable casing, which confines the gases of combustion, preventing their escape at all points, except the chimney, which is situated to one side. Here a forced draught is maintained by exhaust steam, as in a railroad locomotive, and the smoke and burned gases, having no other vent, are compelled to pass out through the small spaces between the slanting tubes, thus giving off a very large percentage of their heat.

Steam is taken off through the vent shown at the left hand top of the upper chamber, and is fed to the engine through a steam dome. Later patterns of this boiler have also a superheating coil, which carries the steam from the upper part of the chamber to a point directly over the fire, and thence out through this same vent. Water is fed to this boiler by a pump worked by a worm gear on the crank shaft of the engine, or by an injector, when the machinery is not in motion. Two safety velves are also provided; one blowing off into the chimney, the other, situated at the top of the steam chamber, into the air.

With a generator of this description, something over 3 feet in height, 83 square feet of heating surface is obtained on about 2.4 square feet of grate area. Its usual working pressure is about 175 pounds per square inch, with test at 350 pounds, and sufficient steam is developed to give 20 B. H. P. at 440 revolutions per minute, which represents 1 horse-power at the boiler for each 4.15 square feet of heating surface. Such an average indicates a highly efficient generator.

The "Lifu" Boiler.—One of the most elaborate attempts to utilize the water tubes to promote circulation is shown in the "Lifu" boiler, which is used on the wagons of the Liquid Fuel Engineering Co., of England—the name of the boiler being derived from the first syllables of the first two words. Most of the general structural points may be understood from the figure, which shows three principal parts; a circular trunk tube at the base, from which a large number of curved tubes lead to the steam drum shown above. In addition to these the trunk tube is also connected to the bottom of the drum by a water connecting arch, both legs of which are cast in one piece with it at opposite sides. This water arch makes the circulation complete along natural lines. The water tubes are connected to the trunk tube three deep and staggered. The connections are made by gun metal union nuts, the same kind of joints being used in joining to the copper steam drum. Each row of tubes, as shown, is given a spiral bend around nearly one-third of the circumference of the drum, about nine inches from the base and in an opposite direction to the next row, so that complete water circulation is en-

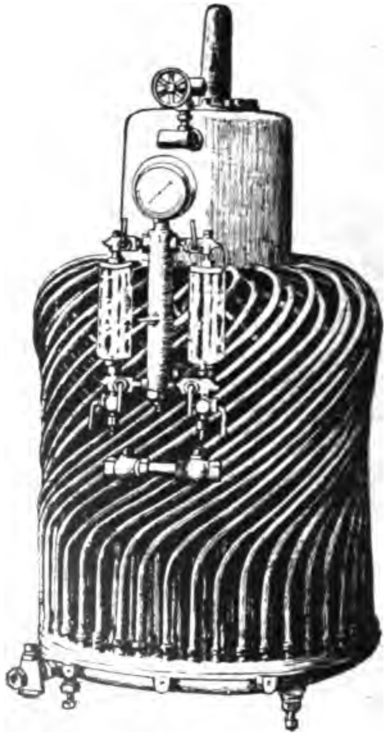


FIG. 409.—The "Lifu" Steam Boiler, showing arrangement and inclination of the tubes. The central steam drum terminates in two legs at the bottom, which are connected at either side to the annular mud-and-water drum at the base, thus completing the circulation.

sured in every direction. The whole structure is enveloped in an iron sheath and packed, and heat is supplied by the gas burner described later.

The Ofeldt Tubular Boiler.—Among the interesting types of tubular carriage boilers may be mentioned the Ofeldt generator, shown in the accompanying figures. As may be seen, it consists of an upright steam and water drum, having a somewhat enlarged head, which serves as a steam chamber. Around this upright drum, and connected to it at top and bottom, are eighteen spirally-twisted steel tubes, which are directly exposed to the heat of the burner, and control the circulation of the water. The construction of these steel tubes permits considerable expansion in directions sidewise of the boiler; thus preventing the natural lengthening of the tubes under the heat of the burner from disturbing the connections at top and base. The burner of this boiler consists of a number of tubes, starting on radii from a central mixing drum, like the steam and water drum already described; each one having pin-hole perforations at the top for the flame and being closed at the end. The vaporizing coil passes over several of the burner tubes.

FIG. 410.

FIG. 411.

FIG. 410.—Top View of the Ofeldt Boiler, showing the feed-water coil surrounding the generating coils; also attachments of generator coils.

FIG. 411.—Side Elevation, showing steam chamber, generator coils and burner.

CHAPTER THIRTY-SIX.

FLASH STEAM GENERATORS.

Serpollet's Flash Boilers.—The first real impulse to the modern steam carriage was the invention by Léon Serpollet in 1889 of the famous "instantaneous generator," known by his name. It consisted of a coil of one and one-half inch lap-welded steel tubing flattened until the bore was of "almost capillary width"—this he later increased to about one-eighth inch—and this, surrounded by a cast-iron covering to protect the steel from corrosion by heat, was exposed to the fire. The result was an extremely rapid generation of steam, the coil being first heated, and the water being vaporized almost as soon as it was injected into the tube. Later, he improved the efficiency of his coil by corrugating its surface. With such a generator of 108 square inches of heating surface more than one boiler horse power could be developed, the average hourly evaporation being forty pounds of water. The usual working pressure was 300 pounds to the

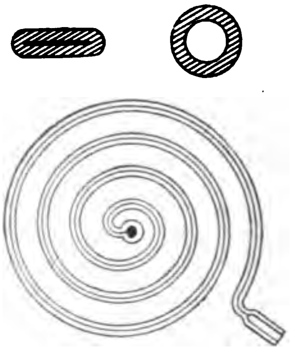


FIG. 412.

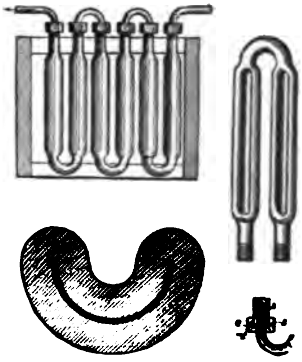


FIG. 413.

FIG. 412.—Earliest Form of the Serpollet Flash Generator; a coil of flattened steel tubing.

FIG. 413.—Second Form of the Serpollet Flash Generator: a series of tubes pressed as shown, bent U-shape and nested; the extremities being connected by joints and bent unions.

square inch, but each tube could bear a test of as high as 1,500 pounds. One great advantage lay in the fact that the high velocity acquired by the steam and water in the narrow tube served to keep the surface thoroughly free from sediment and incrustations. For vehicles requiring an additional generative power two such coils were used, one above the other, the water being injected into the lower and the upper one serving to superheat the steam. To stop the engine it was necessary only to shut off the water feed pump, with the result of stopping the generation of steam at once.

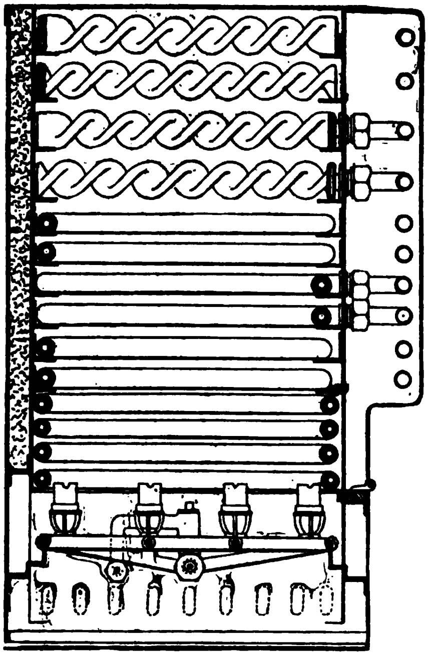


FIG. 414.—**Later Form of the Serpollet Flash Generator**, consisting of three layers of tubing. The four lowest tiers shown form a coil into which the feed water is injected; the second series of six tiers are arranged "zig-zag, ' like the nested tubes shown in Fig. 175; the third, or topmost, series of four tiers are also arranged "zig-zag," but are flattened and then twisted as shown.

In improved boilers of the Serpollet type a number of straight tubes were united by bent joints and nested, the several layers being connected in series. Moreover, each tube length was flattened, so as to form a U-shape, or crescent, in its cross-section, which arrangement greatly increased its evaporating capacity. But the most efficient form was reached in the design shown in Fig 176, which shows three superposed sections of tubing; the lowest, four tiers of coil; the second, six tiers of "zig-zag," the successive tiers being staggered, as shown; the third, several tiers of flattened tube twisted to angles of about forty-five degrees. The water is fed to the lowest section, which is immediately exposed to the fire, being thence passed to the second, whose available heating surface is of the greatest possible dimensions, and finally delivered, as superheated steam, from the upper-

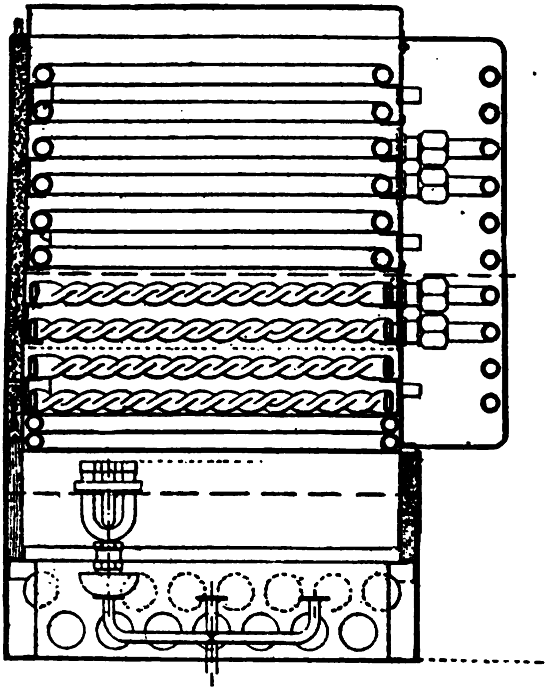


FIG. 415.—Recent Form of the Serpollet Flash Generator. In this type the twisted tubes are placed at the bottom and the "zig-zag" nested tubes at the top. The reason for this arrangement is that twisting the tubes affords a much larger heating surface; hence these tubes are directly exposed to the fire.

most twisted coils. The several sections of tubing are connected together *in series* by bends and unions outside the case, as shown, and the entire generator is enclosed in a double sheet-iron casing packed with asbestos. By the arrangement of the tubing, as here shown, the full power of the heater, in both draught and radiated heat, is utilized, as in the type of boiler shown in Fig. 123, but the circulation of the water is perfectly under control and rapid generation of steam assured. For a six-horse power boiler of this type the outside dimensions, including heater space, are about 2½ x 1½ feet, the total tube length, ninety-five feet, and the heating surface, about twenty-five square feet; giving a generator of convenient size for a four-seat road carriage.

Of Flash Generators in General.—Following along the lines of Serpollet's famous "flash" generator, with its numerous advantages in point of quick steam, high pressure capacity, freedom from scale deposits, and complete immunity from explosion, several designers of steam carriages and wagons have produced improved "boilers" of similar description. Serpollet's first generator, as applied to his light steam carriage of 1889, was merely a coil of flattened tubing. Later two such coils, connected in series, formed his generator, and finally the complicated trains of coils and bent tubing. In the latest generators described the water is fed to the lowest tier of tubing, and the steam is taken off at the top, as in the several types of coiled water-tubed boilers, already described.

The contrary procedure is followed in most of the really successful flash generators produced by other inventors. The Blaxton generator feeds from the lowest water coil, but the Simpson-Bodman, White, Automobile Manufacturing Co., and others feed from the top and superheat the steam in the lowest coils. This seems to be the most logical process for this type of generator, since, as the water is explosively vaporized by contact with the heated tubes, it follows that the progress should be from the lowest to the highest temperature, vaporizing and superheating the steam, rather than allowing it to follow a course from higher to lower temperature, with the accompanying consequence of loss of heat. By making the tubes of sufficient capacity to vaporize a good quantity of water, surprisingly high temperatures may be obtained in a short time and high power engines may be driven with perfectly dry steam. In these particulars the flash generator is superior to a boiler of any type, although it is probable that its use for light carriage purposes will be very limited.

The White Flash "Boiler."—Among the light steam carriages equipped with flash generators may be mentioned those constructed by the White Sewing Machine Co., and the Automobile Manufacturing Co., the latter an English concern. The White generator consists of twelve superposed plane profile coils of quarter-inch seamless steel tubing, which are connected continuously from top to bottom. The water, under impulse from a

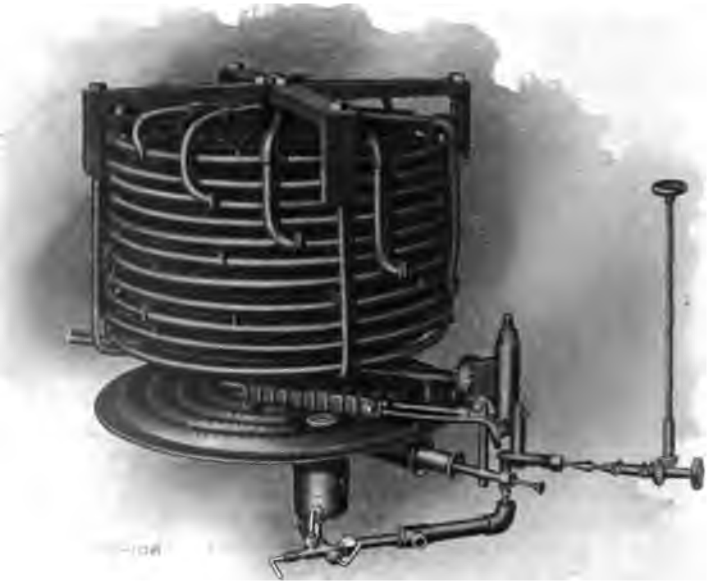


FIG. 416.—Diagram Illustrating Arrangement of the Vaporizing Coils of the White Flash Generator, Elevation. The water is fed into the centre of the top coil, flowing all around that coil and, *in series*, through every other coil in succession. It is "flashed" into steam somewhere above the lower coils, being taken off from the bottom one. The steam pipe rises to the top of the generator, as shown.

plunger pump operated from the crosshead of the engine, as in most steam carriages, enters the top coil at the centre point, flowing thence around the tube to the outer extremity of the coil and over again to the centre of the coil next below. The same connection of outer and centre extremities is maintained throughout the entire series of coils until the bottom one is reached. Here the connection of the outer extremity is to the top of the generator case, where is the steam out-take. This arrangement may be readily understood on examining the diagram.

The water, pumped into the top coil, passes entirely around, and thence through each coil continuously, until the bottom coil is reached. Somewhere in the downward travel it becomes vaporized, and by the time it emerges from the last coil it has become superheated steam. The amount of water actually fed to the coils is determined by a diaphragm regulator, which controls a by-pass valve, operating to return any surplus feed to the tank. The feed is thus interrupted when the pressure falls—which fact indicates the presence of too much water in the tubes, since the amount of contained water and the total pressure per square inch are in inverse proportion. By this means the operation of the generator may be maintained automatically at a uniform point; its output efficiency and the rapidity of steam generation being dependent on the amount of fuel consumed by the burner, which fact determines the heat of the coils.

The pressure is indicated by an ordinary steam gauge, which shows a normal working pressure of 200 pounds per square inch, that being the point at which the tension of the regulator spring is adjusted. The safety valve, however, is adjusted to blow off at 500 pounds, a pressure which the coils are said to be able to withstand. Under usual conditions of operation the steam may be superheated to about 800 degrees. As in all flash generators, no water is fed to the coils when the engine is not working, and the first essential act in starting work is to begin feeding by hand, which it is necessary to do no longer than to provide for the generation of steam for the engine. The generator is of the usual size of light carriage boiler, when encased in its sheet iron and asbestos packing cover, and runs a 6-horse-power engine.

The automatic regulator used on the White steam generator is a true thermostat device, like that used on the Blaxton generator, although regulating the fuel supply rather than the burner flame.

Its position and connections are shown on the figures of the White water feed system, where it is designated as *Q, R, S.* As shown in an accompanying figure, it is constructed as follows: A tube, *A, A, A,* extends entirely through the diameter of the generator, forming, in fact, the connection between the two lowest coils of the White steam generator, and being connected at one end on the point, *Q,* and at the other on the sleeve there shown. Within this tube, *A,* is another one, *B,* secured, as shown, to the head piece at the right hand end of the tube in the figure. This second tube is preferably of copper, and around it, within the tube, *A,* the steam circulates freely between the two lowest coils, so long as the generator is in operation; thus determining its temperature and consequent expansion. Within this second tube, *B,* again, is the rod, *C,* preferably of iron or steel, whose ratio of expansion is smaller than that of copper for all usual boiler temperatures. This tube, *C,* bears upon the bell crank, *D,* normally holding it in the position shown. When, however, the temperature of the steam or air within the tube, *A,* has reached a certain predetermined maximum, the tube, *B,* of copper, expands accordingly, lengthening in the direction of the left of the figure, on account of being rigidly secured to the head at the right. The result is that the linear expansion of *B* and *C* being unequal, *C*

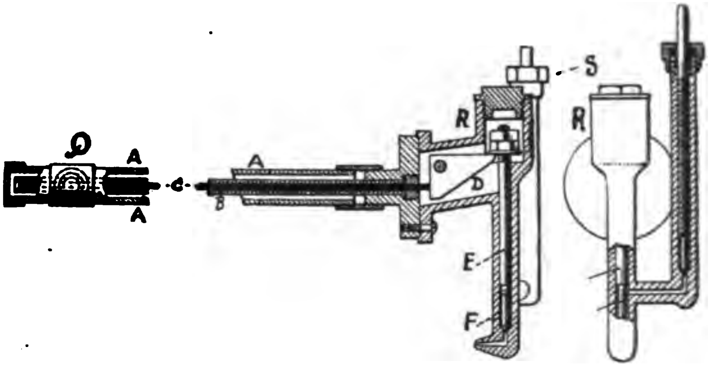


FIG. 417.—The White Thermostat Fuel Feed Regulator. A is a tube extending clear through the body of the steam generator and forming the connections of two of the coils, as at Q. B is a tube contained within A, and around which steam circulates; C, a rod contained within B; D, a bell crank regulating the valve, E, as C lengthens with heat; F, the point of the valve. R is the valve chamber, and S the gasoline inlet chamber regulated by a needle valve on a screw-threaded rod.

is drawn away from the bell crank, *D,* with the result that the rod, *E,* is allowed to fall accordingly, decreasing or quite closing the needle valve at *F.*

The Blaxton Flash Generator.—The Blaxton generator, although differing in several important particulars, is constructed on the same general theory, consisting of a number of superposed plane-profile coils of tubing, through which the water is passed in series, from the lowest coil to the top, where it is taken off as steam. As shown in the figure, the water fed from the pump passes direct to the centre of the lowest coil, thence around to the outer extremity, and to the centre of the second coil. The connections between the coils of tubing are made by nut joints and unions outside the casing. The feed water is pumped in by

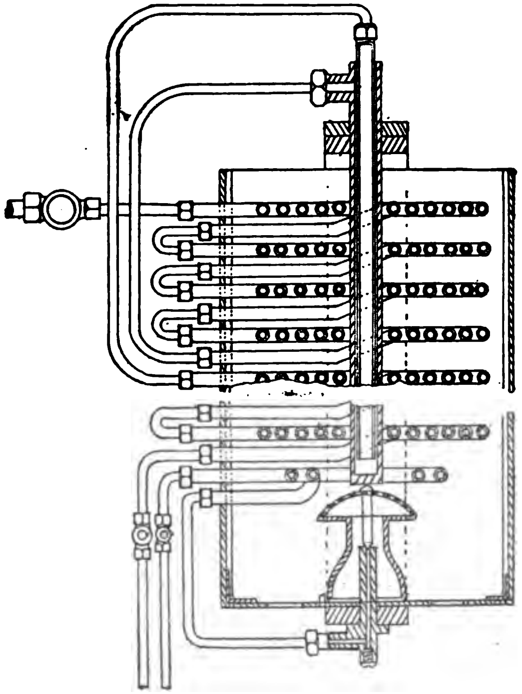


FIG. 418.—Sectional Elevation of the Blaxton Flash Generator.

hand until sufficient steam to operate the engine is obtained, precisely as in other flash generators.

The particularly interesting feature of the Blaxton generator is the device employed for automatically maintaining the consumption of fuel and of steam at one ratio. As shown in the diagram, the fuel oil is pumped into the short coil placed lowest in the case, and, being vaporized by the flame, passes around to the burner. Directly above, and nearly touching, the burner is a vertical tube, closed at the lower end and containing a second somewhat shorter tube.

The water, in process of vaporization, passes from the outer extremity of one of the coiled elements directly into the inner of these two tubes, the circulation being completed when it passes up between the inner and outer tubes, through a joint, into the centre of the coil next above. By this means the temperature, and consequently the length, of the outer tube is regulated. For, so long as the feeding of cold water continues, the water or steam, passed through this tube, absorbs a large percentage of its heat, thus preventing unusual expansion lengthwise, but, when the supply is cut off, or when, from any cause, the heat becomes too great, the tube elongates, and, pressing down upon the gland of the burner, closes the needle valve that controls the fuel supply. By this means the life and usefulness of the generator is prolonged, as much as possible, since overheating is prevented by the constant closing of the fuel feed valve. The Blaxton generator is thus rendered more highly efficient than most of the average "flash boilers," whose greatest drawback is the constant tendency to burn out, if left long exposed to heat when no water is being fed to the coils.

The generator herewith illustrated measures 5 feet 9 inches in height and is 3 feet square. It contains 126 square feet of heating surface, has a normal working pressure of 200 pounds per square inch, and can propel an engine of 25 horse-power. This average on heating surface is about equivalent to that of a good water-tube boiler, although here steaming is more rapid.

The Simpson-Bodman Flash Generator.—The Simpson-Bodman flash generator is probably the best known after that of Serpollet, although its use on motor vehicles is confined to the heavy tractors and lorries built by the firm. Briefly, it consists of a number of tiers of bent tubing connected in series with the form of connector, known as the Haythorn joint, very much after the manner of Serpollet's later generators. Unlike Serpollet's tubes, however, the portions here exposed to heat are not flattened or twisted, but indented, as shown in an accompanying figure, after the manner of the Rowe tube, so called from the inventor of the process. The tubes are also of larger diameter and thicker walls than those used by Serpollet, and, according to the claims of the manufacturers, can withstand a test pressure of one ton (2,240 pounds) to the square inch.

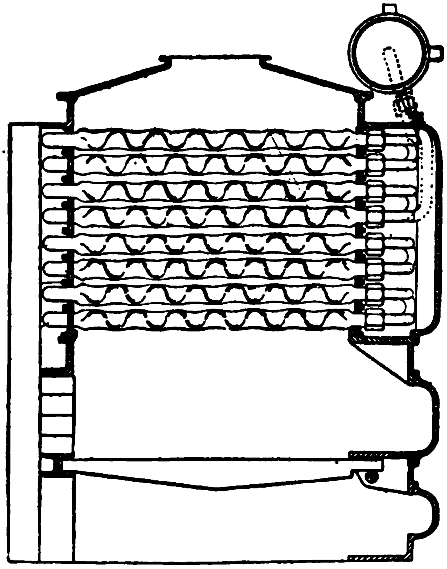


FIG. 419.—Sectional Elevation of one Form of the Simpson-Bodman Flash Generator and Casing, showing the steam drum at the right top of the casing, through which the feed water is pumped to the indented "Row" tubes, bent double, arranged "zigzag" and nested, like the tubes of the Serpollet generator shown in Figs. 175, 176, 177. The connections between the tubes outside the casing are by U-connectors and Haythorn joints.

With a generator of this description consisting of twelve two-legged elements, or double tubes, each leg indented through a length of 2 feet 6 inches, 3½-inch pitch of indent—which gives a total heating surface of 46 square feet—and a grate area of 2¾ square feet, an efficient temperature of 400 degrees, Fahrenheit, has been obtained in 25 minutes from kindling the fire, and a working pressure of at least 250 pounds per square inch in 30 minutes. In fact, it is necessary, with this generator, to provide against too high a temperature of steam—it is not unusual under running conditions that it reach a temperature of 1,000 degrees, Fahrenheit, which would, of course, decompose the lubricating oil, if admitted to the cylinder. Consequently, an essential feature of construction is the steam drum, which is an elongated cylinder containing one or two U-shaped tubes. The steam is let into this drum, and the feed water on its way to the top coil, passes through the U-shaped tubes, thereby absorbing a goodly proportion of the superfluous heat. On leaving the drum, therefore, the steam has reached a temperature sufficiently low to be fed to the engine.

Instead of using any device for regulating the heat, or opening the by-pass valve, a back-pressure valve is fixed on the feed pipe between the by-pass and the generator, which, it is said, furnishes a much more economical means of dealing with over-supply of water than that of returning it to the tank. The steam is allowed to collect in the drum, and superfluous pressure is relieved by an ordinary safety valve loaded fairly high. This insures a ready supply of steam on hand to start the engine, instead of resorting to the usual method of pumping in water with a hand pump.

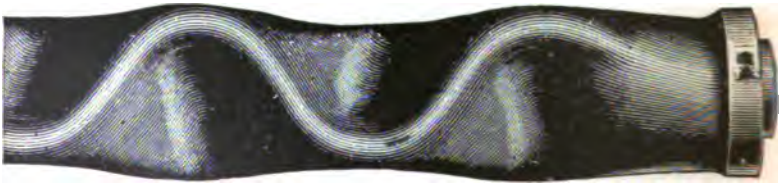


FIG. 420.—Length of "Row" Tube, such as is used on the Simpson-Bodman Generator for Producing an Enlarged Heating Surface. This cut shows the manner of making the indentations.

CHAPTER THIRTY-SEVEN.

THE TESTING AND REGULATING ATTACHMENTS OF STEAM BOILERS.

Boiler Attachments: Try-Cocks and Water Glass.—In operating a boiler of any design it is essential both for safety and efficiency that the engineer should be kept constantly informed on the level of the water and the pressure of the steam. For this reason boilers are fitted with try-cocks, water glass and steam gauge, all of which are depicted in accompanying figures. There are usually three try-cocks, as shown, the upper one intended for steam, the second at the working level of the water, and the third at a fixed point above the fire line. In conditions of uncertainty in the action of the water glass the engineer may find out whether the water level is too low by opening the lower cock, or may find if it is too high by opening the two upper ones. In making test it is necessary to leave the cock open sufficiently long to discover whether all steam, all water, or a mixture of both is escaping. In large boilers it is desirable thus to open the try-cocks several times a day.

The water glass, or water column, furnishes a ready means for determining the exact height of the water in the boiler. It consists of two cocks opening into collars arranged to be connected by a length of glass tubing, as shown in the figure. By opening these cocks the height of the water may be seen in the glass tube. Since it is such an important consideration in boiler operation that the water level should be constantlv watched, it is necessary that the water column should be placed where the engineer may constantly observe it. Thus it is that, in steam carriages it is disposed in the side of the body beneath the seat, its condition being readily observable by the driver by reflection in a small mirror set to one side of the dashboard. Lamps are also arranged behind it, so that the level of the water may be observed at night.

The water glass also gives information on the condition of the water within the boiler, as when oil or scum has collected on the surface, causing foaming. Then the uneven fluctuations in the water level indicate the condition beyond doubt. When this condition is noted it is time to blow off the boiler, or, at least, to observe carefully its operation.

Troubles with the Water Glass.—Troubles with the water glass that must be constantly guarded against are stoppage by sediment and the breaking of the glass tube. The former difficulty may generally be remedied by closing the lower cock and allowing the steam from the upper one to blow through the drain cock shown at the bottom. In case the glass tube be broken it is necessary only to close both cocks, and insert a new tube in the collars, having first removed the nuts and packings at top and bottom. In order to obviate, as far as possible, breakage of the glass it is necessary to avoid too sudden changes of tem-

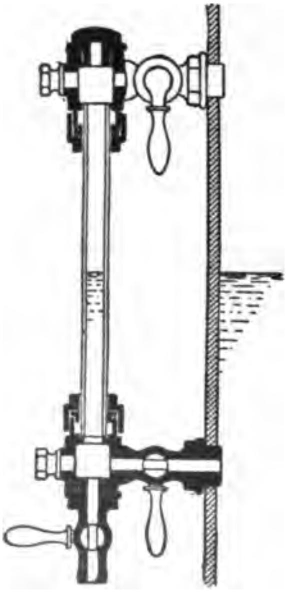


FIG. 421.

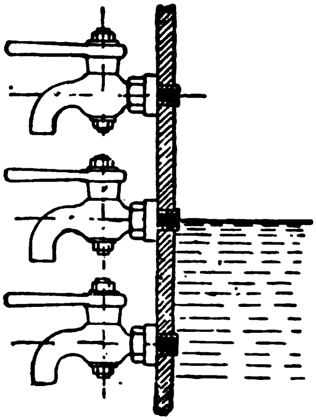


FIG. 422.

FIG. 421.—Sectional view of a water glass, as used on large boilers, showing water level and sections of stop-cocks, drain-cock, tube packing and retaining nuts.

FIG. 422.—Section on boiler shell showing the designed position of the try-cocks: the center one coming at about the average water level.

perature in the column, when first opening the cocks, after getting up steam.

Most of the water glasses used on steam carriage boilers have self-closing valves, which operate to prevent the escape of steam in case the glass is broken. In the use of these valves particular care is needed, since they are very liable to be clogged with sediment or incrustation, causing false indications of the water level and enabling the boiler to be burned out before the driver knows that anything is wrong. Several carriage owners, in the writer's experience, have had these valves removed, and contented themselves with closing the cocks every time the glass is broken. This may be a rather exceptional experience, but it is extremely desirable, if not imperative, to verify the water glass reading by the try-cocks before starting the carriage.

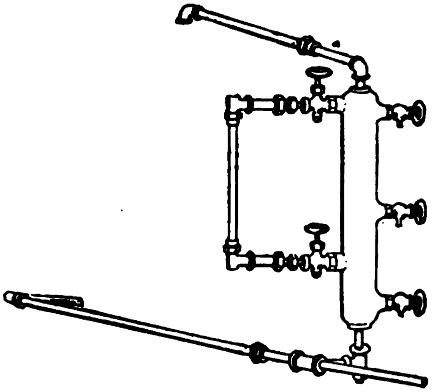


FIG. 423.

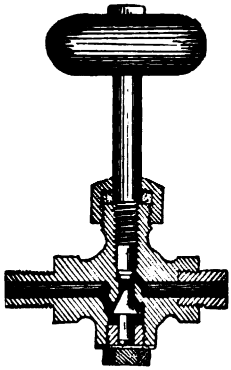


FIG. 424.

FIG. 423.—Water column, try-cocks and water glass of the "Locomobile" Carriage. The water column is connected to the boiler at top and bottom, as shown. The continuation of the lower pipe to the right leads to the steam gauge.

FIG. 424.—Type of check valve for a water glass. As may be seen, the cone-shaped valve remains in the position shown, so long as the pressure is the same at both sides. When the water glass is broken, the steam, coming through the pipe at the left, causes the valve to rise into its seat, thus closing the opening.

The water glass is an important piece of mechanism, and cannot be too closely observed and cared for. Skilled engine drivers take its record constantly, and so very important is it that no error regarding the water level should be made that some inventors have proposed using colored floats to attract the driver's eye, and enables readier reading of the record. A supply of glass tubes should always be kept on hand in a steam carriage so that breakage may be immediately repaired. Also, every possible precaution should be adopted to prevent the accumulation of sediment that might obstruct the free passage of the water into the glass. It is well to clear the tube by flushing with steam at frequent periods.

The Steam Gauge.—As a means of determining the power output, a steam gauge is attached to all well-appointed boilers.

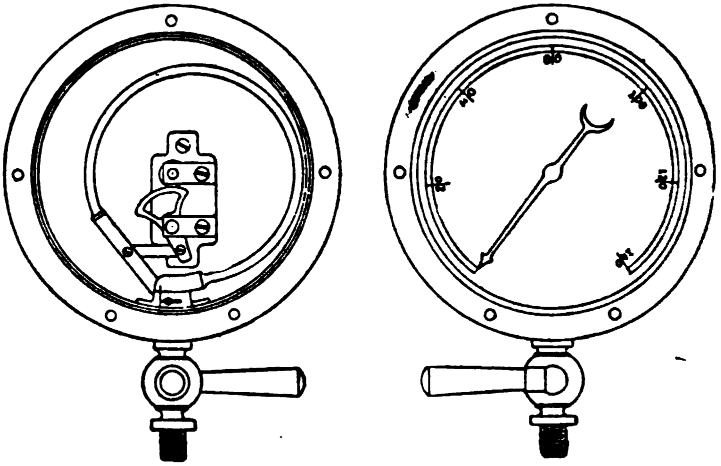
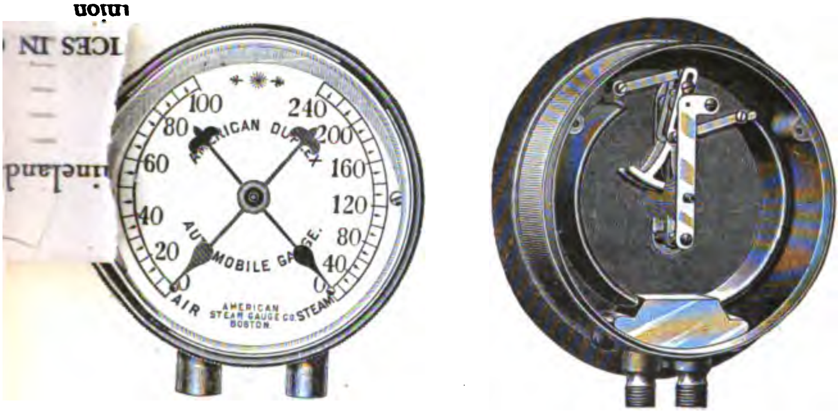


FIG. 425.—Interior View and Dial Face of one Type of Steam Gauge. The steam is admitted through the cock at the bottom of the dial box into a flattened and curved tube, which it causes to straighten slightly by its pressure, thus operating the sector and the hand on the dial plate.

This device indicates on a dial the degree of pressure generated within the boiler. Steam gauges are constructed with one of the two varieties of internal mechanism. In the first variety the steam bears upon a diaphragm, regulated to yield in proportion to the pressure exerted. The second variety operates through the tendency of a flattened and bent metal tube to straighten out under pressure of the steam or gas within it. As shown in an accompanying figure, a tube, flattened to an ellipsoidal cross section, is connected by one end to a steam pipe leading direct from the boiler. When the cock is opened, steam is admitted to the tube,

ressure tending to change the flat section to one more nearly
d, and in the process causing the tube to begin uncoiling it-
in the direction of a straight line conformation. Hence the
end of the tube, attached, as shown, to a link connected to
er bearing a toothed segment, tends to move, causing the
to move the lever. As the lever is dragged by the link, the
ed segment actuates a pinion carrying the hand of the dial
s spindle, thus indicating on the dial the pressure at work
e tube.



FIGS. 426, 427.—Dial and Interior View of the "American" Duplex Combined Steam and Air Pressure Gauge for Use on Steam Carriages. The dial has two hands; one of them attached to a sleeve which works over the spindle carrying the other, in the same manner as the two hands of a clock are hung. As may be readily understood, the two hands work in opposite directions, one clockwise, the other counter-clockwise, from zero to maximum on their respective scales. The sectional view shows the mechanism by which this result is accomplished: two separate inlets, for steam and air, respectively; two distinct flattened and curved steel tubes, each attached at its end by a link to a lever and toothed sector working on the toothed pinion concentric with the pivot of one of the hands. The two flattened tubes, of course, have different tensile ratios, causing them to tend to straighten at different pressures. Hence the steam hand records a maximum pressure of 240 pounds, while the air hand records a maximum pressure of 100 pounds.

Cause and Danger of Excessive Pressures.—Since every boiler is calculated to supply steam to its engine at a certain maximum working pressure—with light steam carriage boilers the usual working pressure is between 180 and 200 pounds—the driver can readily find from his gauge whether or not full power is being generated. Exceptionally high pressures under working conditions indicate a danger point, and in small boilers they are very often due to a low water lever, which, unless remedied, will result in burning out. A carriage boiler holding a proper supply of water cannot derive sufficient heat to generate pressures above a certain fixed point, because, as will be explained presently, the fire is automatically regulated. If, however, the water has become exhausted, even though an excessive pressure acts to shut off most of the fuel supply, the metal of the boiler will become sufficiently heated to collapse the tubes. It is the "dry heat" that is most to be feared in boilers.

So far as the test resistance of small boilers is concerned, they should be able to endure pressures far beyond the "blow-off point" of the safety valve. Several American carriage boilers are

FIG. 428.

FIG. 429.

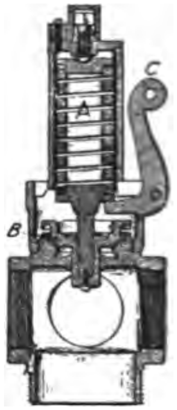


FIG. 430.

FIGS. 428, 429.—Two Types of Low-water Alarm.

FIG. 430.—Section of a Type of Automobile Pop-safety Valve. A, the spring; B, the valve; C, regulating lever.

advertised to have been tested at a "cold water pressure" of 1,000 pounds and over to the square inch. This test is made by injecting water under such a pressure mechanically exerted or by filling it from vertical tubes of considerable height. However, in the absence of heat, this indicates only the tensile strength of the metal. For obvious physical reasons, this is quite a different thing from the conditions brought about by the action of the heat.

Safety Valves; Construction, Theory and Operation.—The design of the argument up to this point is to satisfy the reader that explosion in a steel-shell, copper-flued carriage boiler is very nearly impossible, and, further, that moderate care and watchfulness can prevent the burning out or collapse of the flues. The unskilled engine-driver is amply protected, if he only exercises reasonable prudence by the automatic burner regulator, the automatic low water alarm, the water glass and steam gauge in plain sight, and lastly by a safety valve adjusted to blow off at the proper pressure.

A safety valve is simply a valve of ordinary description, arranged to close a steam pipe outlet, under pressure of a weight or spring.

The safety valves used on steam carriages are constructed on the same general principles as any of the spring valves used on locomotives, or other boilers. They are usually known as "pop" valves, from the fact that the steam in lifting the valve from its seat usually makes a "pop" or sudden detonation. As a usual thing carriage valves are adjusted to a fixed pressure, which is never disturbed.

The Blow-Off Cock.—This is an important attachment of all boilers, furnishing a ready means of removing the water from the boiler under pressure of its own steam, which is called "blowing-off." It is also used in some carriages for attaching a hose to fill the boiler at starting, or for injecting water for cleaning the interior. It is usually closed with a box nut for receiving a wrench, but sometimes by a cock, as in large boilers.

CHAPTER THIRTY-EIGHT.

BOILER FEEDERS AND WATER LEVEL REGULATORS.

Of Boiler Feeders in General.—There are two different kinds of device for feeding water to steam boilers: plunger pumps operated by the engine or by a separate cylinder; and injectors, which raise and feed the water by a steam jet from the boiler itself. Injectors are largely used for locomotives, marine and stationary boilers, but to the present time almost not at all in steam road carriages. The principal reason for this is that the valves and apertures in an injector, suited for a light carriage boiler, would have to be made so small that they would be constantly clogged with dirt and sediment, hence rendering the instrument inoperative. Furthermore, when in operation, an injector would be liable to fill the boiler too rapidly, while the pressure remained sufficient to raise the water, thus causing priming; and, if shut off until the water level had fallen considerably, would cause damage to the boiler by flooding it, while in an overheated condition.

Plunger Pumps and By-Pass Valves.—The plunger pumps used to feed steam carriage boilers are most often operated from the cross-head of the engine. Consequently, so long as the engine is in motion, water is steadily pumped into the boiler. When, as shown by the water-glass, the level is too high, the by-pass valve may be opened, and the water pumped from and back again to the tank. In some carriages the by-pass is always operated by hand; in others it is also controlled by some kind of automatic arrangement. The automatic control of the by-pass is extremely desirable, particularly since unskilled engineers most often have charge of carriages and are exceedingly liable to forget the small details of management. On the other hand, many automatic devices get out of order altogether too easily, and leave the carriage driver to exercise his skill and judgment at an unexpected moment.

In addition to the danger of flooding the boiler, the opposite embarrassment often occurs—owing to some disarrangement the pump may fail to feed enough water to the boiler, or may not operate at all. Then it is necessary to use a supplementary feeder, generally a hand pump, or a steam pump operated by a separate cylinder. Such supplementary steam pumps and injectors are commonly arranged to start automatically, as required, but may also be started by a hand-controlled valve. Another advantage involved in the use of automatically controlled steam pumps is that water may be fed, as required, to the boiler, after the engine has ceased motion, and it is desirable to leave the carriage standing with steam up. In this condition, however, a very small amount of water is needed, except under unusual conditions.

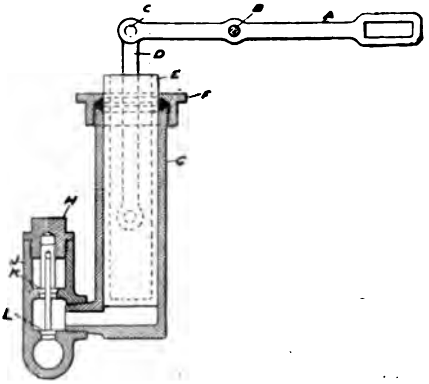


FIG. 431.—Section of a Type of Plunger Feed Pump. As is obvious, the valve opened by suction of the up-stroke is closed by compression of the down-stroke, and *vice versa*. This pump is equipped with a double, or compound, valve, which, as may be seen, secures perfect balance in operation with the simplest possible constructions. The stem of the suction valve enters a bore in the stem of the outlet valve. Referring to the lettered parts: A is the pivoted lever working the pump from the crosshead of the engine; B, the fulcrum point; C, the attachment of the piston rod, D; E, the trunk plunger; F, the packing cap; G, the pump cylinder; H, nut on the valve chamber port; J, the valve chamber; K, water outlet valve; L, water inlet valve.

Operating the By-Pass Valve.—The driver of a steam carriage must constantly watch the water-glass in order to inform himself as to the water level in the boiler. On noticing that the level is too high, or is rising too rapidly—the proper level is generally about two-thirds up the glass—he opens the by-pass valve by turning a small wheel placed near the throttle lever beside his seat. This act, as already suggested, turns the water forced by the pump back again into the feed tank, a three-way cock controlling its travel.

If, after the water has been led from the boiler for some time, the level begins to sink, it is necessary only to close the by-pass valve, thus resuming the feed. If, from any cause, the pump seems unable to keep up the water level in the boiler, and the reading of the water-glass is verified by the try-cocks, thus showing that it is working perfectly and is unclogged with sediment, a few strokes of the auxiliary hand pump will suffice, if no automatic steam pump be attached to the carriage.

Troubles With the Pump.—Since the small water pumps attached to steam carriages are of the simple plunger type, failure to supply sufficient water to the boiler may generally be attributed to loosened packings or to clogged check valves. The rapid sinking of the level in the water-glass will indicate trouble with the pump, except when ascending a high hill. In the latter case the fall of level may reasonably be attributed to the unusual steam consumption. Under usual circumstances, the trouble is due to loosened packings, and this trouble may be remedied by inserting new packings, although particular care should be exercised, so as not to pack the plunger too tightly and cause breakage. If it seems evident that the falling water level is due to clogged check valves—this is a comparatively rare occurrence—the fire should at once be extinguished and the check valves opened and cleaned.

Flash Boiler Feeders: The Serpollet System.—The feeding apparatus for shell and water tube boilers is to be adjusted, either automatically or by hand, solely with reference to the maintenance of a proper water level. With the feeding of flash generators, however, the operation of automatic devices depends solely upon maintaining a certain predetermined pressure and temperature, which are properly in ratio to the quantity of water being vaporized in the tubes, as is not necessarily the case with generators of other types. It is possible, therefore, to maintain the feed at the proper rate and quantity by automatic pressure regulators, such as are used in connection with steam carriage burners, or else by some system of uniform regulation for fuel and water pumps.

The latter theory is adopted in the Gardner-Serpollet system. As shown in the diagram, the fuel is fed to the burner, and the water to the boiler, through pumps, both of which are operated from the same shaft. The fuel pump is smaller than the water pump and its stroke is also shorter, as is obviously necessary. This is accomplished by the use of a stepped cam, consisting of a row of eccentric discs, of varying eccentricity, which, placed upon the rotating shaft, may be slid in either direction, thus varying the lift. By shifting the cam inward toward the driving spur the strokes of both oil and water pumps may be varied from zero to maximum; the cam surface being efficient in giving a greater or shorter inward stroke, and in permitting an outward stroke of equal length under stress of the spiral spring attached below the pump-operating lever. These operations may be readily understood by a study of Fig. 433, which is sketched from the machine actually in use.

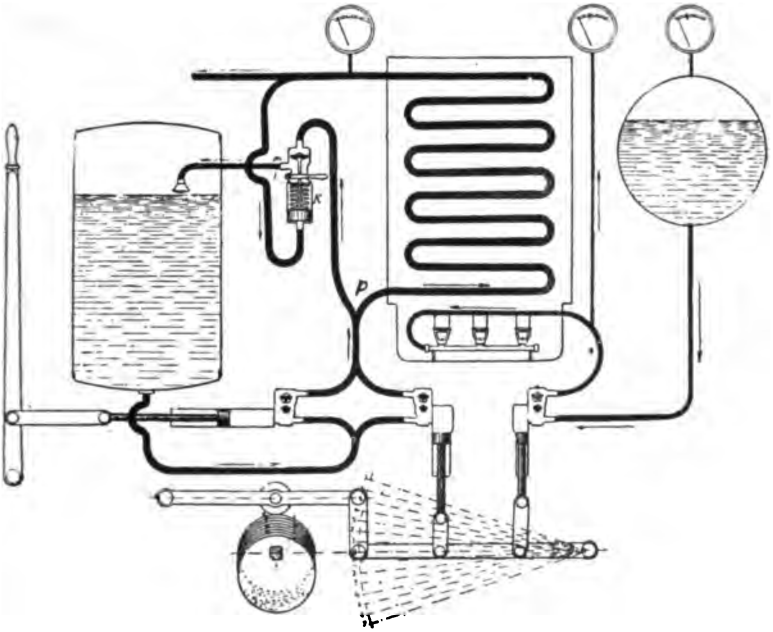


FIG. 432.—The Serpollet Water and Fuel Feed System. The method of hanging the stepped cam controlling the pump stroke may be here understood.

The liquid fuel and the water, being thus varied in the amounts given forth by the pumps, are forced, the one into the vaporizing tube, passing over the burner, the other into the flattened and nested tubes of the generator. By this means the heat is increased in ratio with the quantity of water injected, and the working pressure may be regulated to any desired limit. When, however, the pressure has risen above a certain fixed point—it is generally fixed at about 355 pounds per square inch—it is able to open the spring safety valve, shown attached to the steam pipe, thus also opening the by-pass, so that the water from the feed pump is thrown back into the tank. The water from the pump may be forced through the spring valve, instead of into the generator, by the closing of a check valve at *P*, under steam pressure. The connections may be readily understood from the diagram, which also shows a hand-operated pump for making the initial injection of water into the generator tubes previous to starting the engine.

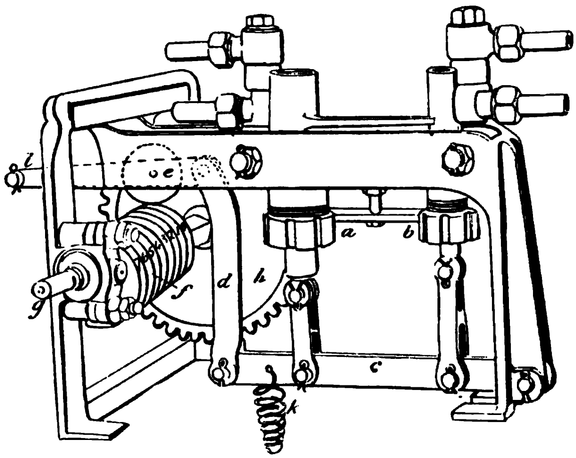


FIG. 433.—Serpollet's Fuel and Water Pumps. The water pump, *a*, and the fuel pump, *b*, are operated from the lever, *c*. This is given an up-and-down movement by the link, *d*, whose stroke is varied by the stepped cam, *f*, on which bears the roller, *e*, on the rod pivoted at *i*. The rotary movement of the cam shaft, *g*, is imparted by the spur wheel, *h*.

The construction and operation of the automatic by-pass regulator, or "safety valve," may be understood from Fig. 434. Strictly speaking, a flash generator needs no safety valve, but its operation demands some method of preventing flooding when the pressure is high enough.

The White Flash Boiler Feed System.—The water-feed system of the White steam carriage flash generator is based on a different theory, although the by-pass valve is controlled by a spring and pressure device, as with Serpollet. The details of the system may be understood from the accompanying diagrams, which exhibit all the essential features. A plunger pump, *A*, operated by a pivotal lever from the crosshead of the engine, *B*, forces water from the tank, *C*, through the pipe, *D*, which, however, divides into two branches at the point, *E*, one portion of the water being forced by the pump through the pipe, *F*, to the coils of the generator, *G*. The pipe, *F*, has the air-chamber, *H*, located, as shown, between the pump and the steam generator. An-

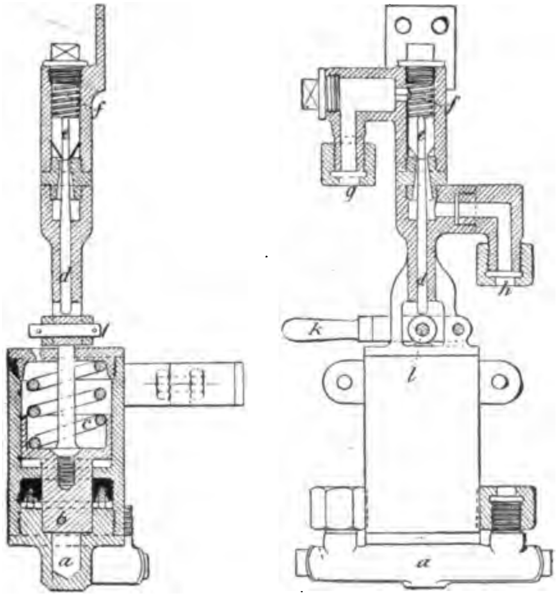


FIG. 434.—The "Safety Valve," or Automatic By-Pass Regulator of the Serpollet Boiler Feed System. The steam, admitted through the tube, *a*, after it has reached a certain pressure, opens the valve, *b*, compressing the spring, *c*. By this action the rod, *d*, forces up the valve, *e*, and the spring, *f*, thus enabling the water from the pump to pass from the pipe, *g*, through the pipe, *h*, to the water tank.

other portion of the water coming through the pipe, *D*, passes through the pipe, *J*, which communicates with the lower chamber of the pressure regulator, *K*, to be described later. Since the

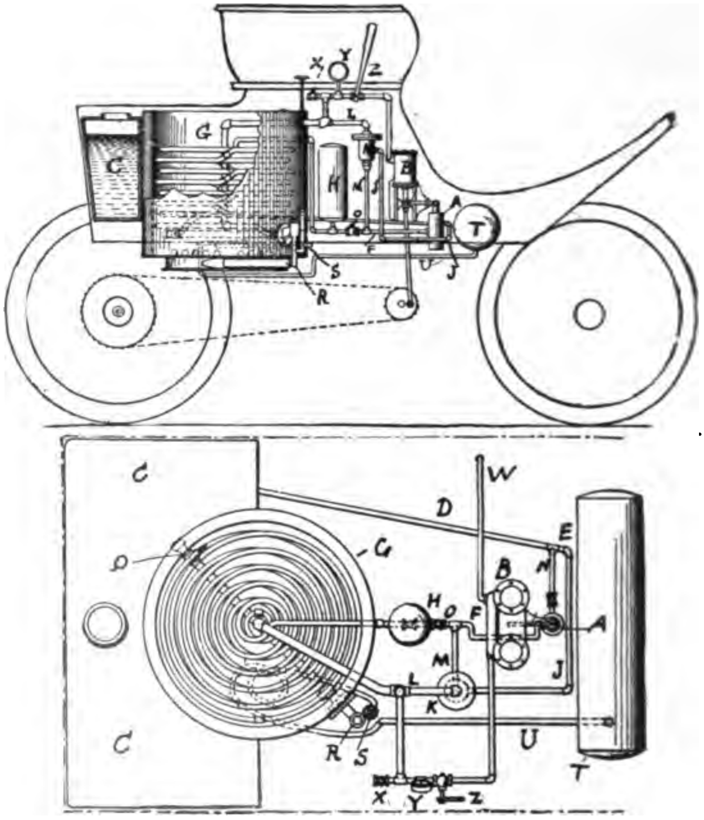


FIG. 435.—**Diagram of the Fuel and Water Feed System of the White Steam Carriage. A is the water pump operated from the crosshead of the engine, B. C is the water tank; D, a pipe leading to the pump, and branching off at E, as shown, into J and N. F is the boiler feed pipe leading through the check valve, O, and the air chamber, H. K is the automatic by-pass regulator; L, a pipe leading steam from the generator, G, and allowing the water to circulate through F, M, K, J, E, N, A, whenever steam pressure rises high. X, the pop valve; Y, the gauge; Z, the throttle; T, the fuel tank; U, the fuel feed pipe; Q, R, S, the fuel regulating and vaporizing system explained later.**

regulator, *K*, is operated only when the steam pressure has reached a certain predetermined point, when the by-pass valve is opened, the pipes, *F* and *J*, are not in communication so long as the pump, *A*, operates to feed water to the coils of the generator. *G*.

The regulator, *K*, is constructed and operated as shown in an accompanying diagram. It consists of two chambers, *a* and *b*, which are put into communication on the opening of the valve, *c*, normally closed by the spiral spring, *d*. The rod carrying the valve, *c*, is attached at its opposite end to the head, *e*, which bears

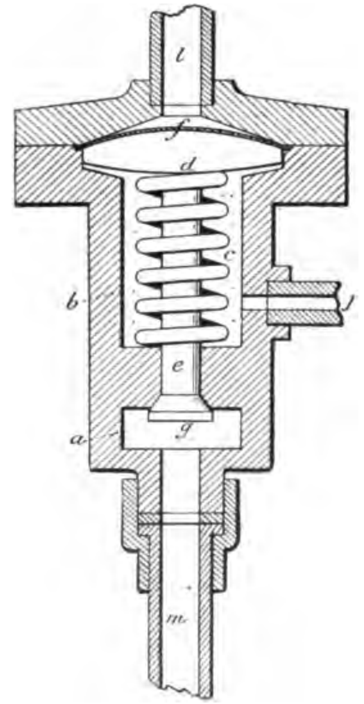


Fig. 436.—Section of the Automatic Boiler Feed Regulator of the White Steam Carriage.

against the metal diaphragm, *f*, held between the casing of *a* and *b* and the cap, *g*. The operation is obvious. The port, *l*, shown just above the diaphragm, *f*, is connected direct to the generator by the pipe, *L*. When, therefore, the steam pressure has risen above a certain predetermined point, which means that a greater force is exerted on the upper face of the diaphragm, *f*, than comes through the head, *e*, from the spring, *d*, the valve, *c*, is opened, making free communication between the chambers, *a* and *b*. Since, now, the ports, *j* and *m*, are on the pipes, *J* and *M*, which are connected in the system, as shown, the opening of the valve *C*, means that the water circulation from the pump, *A*, is through the pipes, *F*, *M*, *J*, *N*; all water being shut from the coils of the generator by steam pressure at the check valve, *O*. So soon soever as the steam pressure again falls to normal, the valve, *c*, is closed by the spring, *d*, and the check valve, *O*, in *F* is again opened, admitting water to the coils of the generator under pump pressure.

In connection with this system of controlling the boiler feed, there is a thermostat regulator, shown at *P Q*, for varying the amount of gasoline fuel fed to the burner, or cutting it off entirely. This, however, will be explained in the chapter on burners and fuel feed regulators.

The "Victor" Steam Air and Water Pumps.—The automatic auxiliary feed pumps used on the "Victor" carriage and shown in section in the accompanying illustration are operated on a principle which has already been applied to the steam air pumps used in connection with the Westinghouse air brake on many American railroad locomotives. As will be seen in the illustration, two such automatic pumps are used on this carriage, the one being intended as an auxiliary feed pump for the boiler, to be used in case the regular feed pump, which is of the double-plunger type, being geared to and operated from the rear axle, should from any cause cease to operate. The other pump is used for maintaining the acquired air pressure in the fuel tank. The steam is admitted through the port marked "steam inlet" in the accompanying diagram; this port leads into an elongated chamber running the full length of the cylinder, and of somewhat enlarged diameter towards the top. Within it, as may be seen is a vertical rod, carrying a piston valve at either extremity. The steam on entering, of course, bears against these pistons, and since the upper one of the two is of the largest diameter, it forces it into the position shown in the cut, thus opening the port into the upper end of the cylinder, and forcing the piston downward. The downward stroke continues until a shoulder at the lower end of the rod, *B*, strikes the nut fixed above *G*, opening the valve, *D*. Communication is thus established between the valve chest, in which slides the double piston rod, *A*, and the space above the piston, *C*. Consequently, steam is admitted above this piston, which, being of larger diameter than the piston below it, forces it and the valve rod downward, thus opening the steam port into the bottom of the cylinder, and so beginning the up-stroke of the piston. The up-stroke continues until the nut above piston, *G*, closes valve, *D*, thus cutting off steam from the space above the piston, *C*, and again causing the plunger to rise. The position of the exhaust valves is such that they are covered by the piston valves on rod, when these are in position to open the inlets, and are opened again as soon as the inlets are closed, thus establishing communication with the exhaust chamber, *F*. The operation of the valves of the pump is obvious and requires no further description.

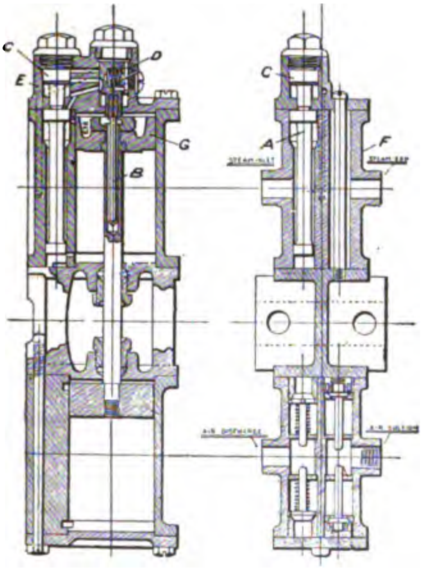


Fig. 437.—Sectional View of the Valve Motion and Mechanism of the "Victor" Auxiliary Steam Pumps.

CHAPTER THIRTY-NINE.

LIQUID FUEL BURNERS AND REGULATORS.

Of Liquid Fuels in General.—All light steam carriages, and many heavier vehicles as well, use liquid fuel, oil or mineral spirit, to produce heat for their boilers. Such liquid fuel is not burned in liquid form, as is oil in an ordinary lamp, but is vaporized by heat, the vapor or gas thus produced being fed to the burner and ignited, in the same manner as ordinary coal gas used for light or heat in houses. It would be impracticable to carry gas in tanks on steam carriages, since the difficulty of storing and replenishing the supply would be greatly increased. By the use of liquid fuels a vast saving is made possible, both in space and weight, while their consumption in gaseous form is another element of economy.

Advantages in Using Volatile Fuels.—A prominent English authority on motor carriages gives the following five considerations of advantage in the use of liquid fuels:

1. Their combustion is complete, no heat being lost in the form of smoke or soot.
2. They produce no ashes or clinkers, which must be periodically cleaned out. Hence there is no loss of heat or drop in steam pressure, due either to this cause or to the renewal of coal.
3. The flues are never incrusted with soot, which involves the best conditions for use of heat.
4. The temperature of the escaping gases is lower than with a coal fire, since there is no need that the air required for combustion should force its way through a thick layer of burning fuel. Whence the uptake temperature is generally about 400°, Fahrenheit, instead of between 600° and 700°, as with the use of coal fire.
5. Since the fuel is burned in fine particles, in close contact with the oxygen of the air, only a small excess of air over that actually required for combustion is admitted to the burner. The opposite is the case with coal.

As may be readily surmised, the calorific value of liquid fuels is far greater than that of coal. It has been estimated that, taking the two weight for weight, petroleum oil has about twice the heat efficiency of coal. Since, therefore, equal weights of both varieties of fuel occupy about equal spaces, it follows naturally that petroleum products are far more economical and serviceable for use in vehicles of any description, or in boats and ships, where the considerations of weight and space occupied, in ratio to the power, are all-important.

The liquid fuels most commonly used are kerosene and gasoline, both being vaporized by the heat of the burner; a kindling flame from liquid gasoline or alcohol vapor, or a specially arranged detachable auxiliary vaporizer, or "torch," being used at the start, and until the vaporizing tubes are thoroughly heated. Kerosene is less suitable for steam carriage burners than is gasoline. A far higher temperature is required to vaporize it, and a larger evaporating surface. Furthermore, it requires large, bulky and complicated burners to consume its vapor, and very frequently produces an excessive amount of carbonaceous residuum, which necessitates periodical cleaning and considerable trouble in generating heat. Gasoline, on the other hand, being a highly distilled product of petroleum, is more readily vaporized than kerosene, requiring generally no greater temperature than may be obtained by passing the supply pipe up through one flue of the boiler and down through another. Such heating as this would have very small effect on kerosene. The burners used for gasoline are simpler and more readily regulated than those used for kerosene. They may also be made much lighter in comparison to their heating power and are less difficult to fire up at the start. All these points are distinctly advantageous, if not imperative, on a light steam carriage, intended for amateur engine drivers. On a heavy wagon, intended to be managed by skilled engineers, they are of less importance, and may be readily superseded by the more complicated devices for using the cheaper fuel.

The Gasoline Burner.—Very nearly the typical gasoline burner for steam carriages is shown in an accompanying figure. It consists of a flattened cylindrical chamber, pierced from head to head by a number of short tubes, each of which is expanded into the holes prepared for it and flanged over to make a secure joint, somewhat after the manner of a well-made boiler flue attachment. These air tubes, as they are called, are open to the air at top and bottom, having no communication with the interior of the cylindrical chamber above referred to. The gasoline enters the chamber, from a nozzle at the end of the feed pipe and through a tube entering at one side of the cylinder and extending inward about two-thirds of the diameter. This tube is called the "mixing tube," and its function is to make a mixture of air and gasoline vapor that will burn readily in the atmosphere. Having entered the cylindrical chamber, there is no avenue of escape for the inflammable gas except through the circular series of pin-holes, which surround each one of the air tubes, as may be seen on the cut of the top of this burner. It is at these minute perforations that the gasoline gas is ignited, the combustion being rendered perfect by the air admitted through the air holes previously mentioned.

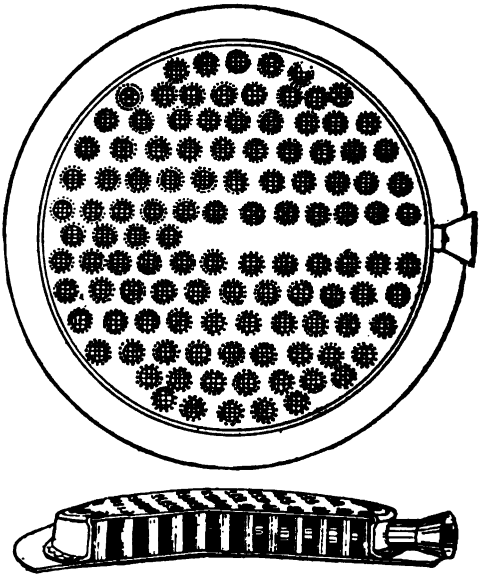


Fig. 438.—Plan and Part Section of a Typical Gasoline Burner for Steam Carriage Use.

The Storing and Feeding of Gasoline.—The liquid gasoline for supplying gas to the burner of a steam carriage is carried in a tank, disposed generally to the front of the body, and sufficiently separated from the burner to avoid all dangers that might arise from leaks or overheating. Within this storage tank a good pressure of air is maintained—generally between 45 and 50 pounds to the square inch—from a separate air tank, supplied by a pump. This pressure is sufficient to force the liquid gasoline into the vaporizing tubes, when the supply cock is opened. After it has been vaporized the circulation continues, as controlled by the steam pressure diaphragm regulator, which operates a needle valve on the tube supplying the burner, the amount of gas and liquid gasoline moving between the supply tank and the burner being thus determined. If the fire is blown out in the draughts created by travel, the difficulty may be generally remedied by using higher air pressures in the tank. Some drivers have used as high as 100 pounds and over.

The pressure in the air tank is produced and maintained, either by a small hand pump, such as is used to inflate pneumatic tires —this method is used on several well-known American steam carriages—or else by some such specially designed pump, as is used on the Victor carriage, or some others described.

The Automatic Fuel-Feed Regulator.—The fuel-feed regulator, of which there are several serviceable forms, is one of the most necessary attachments of a steam carriage. Generally, it consists of a diaphragm, which, actuated by steam pressure from the boiler, automatically closes, or partly closes, a needle valve, thus regulating the amount of fuel fed to the burner. Several such apparatus are shown in section in accompany cuts. There, as may be seen, the diaphragm is fixed across the tube leading from the steam space of the boiler. Against its inner side bears a solid head, or pressure cap, carrying a rod, at the farther end of which is a needle valve. The pressure cap is normally held against the diaphragm by a strong spring. When sufficient steam pressure bears upon the diaphragm, the spring is compressed, allowing the rod attached to the head to be pushed inward, thus regulating the needle valve, according to requirement. The instrument, thus formed, consists of two parts. The one is the pressure chamber containing the spring, whose pressure on the head is regulated by an adjusting screw, through the shaft of which passes the valve rod. The other is the gasoline chamber, into which the fuel for the burner is admitted to the left of the point of the needle valve; its outlet being controlled, as shown, by two hand-wheel valves—one leading to the main burner through the mixing tube, the other being intended to let out a sufficient supply of gasoline to the starting device, which may be a detachable "torch," or auxiliary vaporizer, or some arrangement of drip cup and preliminary generating coil. This arrangement of the valves is shown in different cuts of burners and automatic regulators, being there sufficiently designated. Thus, as shown in the figures,

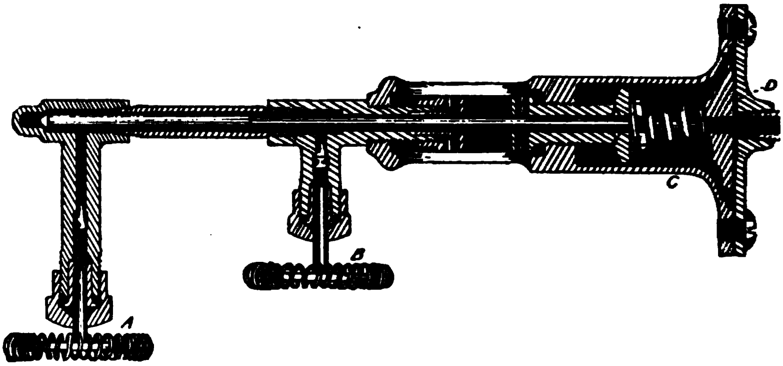


FIG. 439.—Fuel Feed Regulator of a Steam Carriage Burner, Intended for Use with "Torch" Burner Kindler or Auxiliary Vaporizer. A is the hand wheel and needle valve regulating the feed to the main burner; B, the hand wheel and valve for operating the torch; C, the spring and header attached to the main valve rod; D, the diaphragm against which steam bears, regulating the main valve according to pressure. The liquid gasoline is admitted at a port on the left-hand extremity of the regulator tube, near the end of the needle valve on the main rod.

the valve rod, in entering the gasoline end of the regulator, passes through a stuffing box, so as to prevent all leakage at that end.

Of course, until there is sufficient heat generated to vaporize gasoline for the regular burner and generate steam pressure in the boiler, the automatic regulator cannot operate, as described, and the flow of gasoline to the starting burner or vaporizer is regulated solely by the hand valves.

Another form of regulator, shown in an accompanying cut, used on steam wagons, has the advantage of simplicity in this particular, doing away with both spring and stuffing box. The diaphragm has concentric corrugations, and to its centre is attached a valve rod having longitudinal groovings to permit the fuel to enter the feed tube in such quantities as the pressure on the other face of the diaphragm will permit. Steam pressure, being thus brought to bear, tends to deform the diaphragm; hence compressing the valve rod and decreasing the rate and quantity of fuel feed. The fuel is supplied from the storage tank through the port into the lower chamber of the two formed by the diaphragm, as may be readily understood.

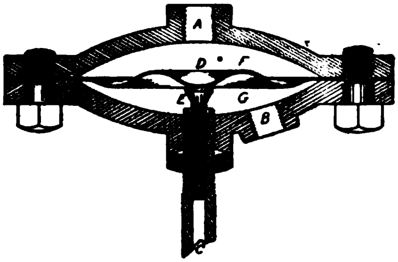


Fig. 440.—Gasoline Burner Regulator, operating with a corrugated diaphragm, like a steam gauge. A is the inlet for steam; B, the inlet for liquid gasoline; C, the port leading to the burner; D, the diaphragm; E, the head on the grooved rod of the valve; F, the steam chamber; G, the gasoline chamber.

Constructional Points on Gasoline Burners.—Several steam carriage burners are formed by riveting together a steel flattened cylindrical pressing and a plane disc, as shown in a former figure, inserting and expanding the draught tubes into suitably arranged perforations, as is done with the flues of boilers. Such a construction is apt to be faulty, however, owing to the fact that the steel plates tend to warp under the influence of heat, causing the draught tubes to leak, and the attachments to wear. The danger of these accidents has moved several inventors and manufacturers to design and produce burners formed with a cast top and steel plate base, or to cast both elements. By the use of castings warping is positively prevented, and leaking at the joints of the draught tubes is obviated.

One of the best-known burners of this construction is that widely known as the "Dayton," which possesses the additional feature of supplying gas for the burner flame through annular openings around each of the draught tubes, instead of using the "pin-hole" design, already described. It is possible to construct with this feature, since the air tubes are cast in one piece with the head and base plates, being afterward reamed out, so as to make them uniform in size. In addition to this air opening, a counter-bore is sunk in the top plate of the burner, and a steel washer is fitted into it, leaving an annular opening for the passage of gas in the inside of the washer. The outside of the washer has a number of small openings in it, so that each air tube is surrounded by two concentric circles of flame. This construction affords a very large heating capacity, and also, as is claimed, prevents the top of the burner from cracking, also less liability of chocking with rust, dust or carbonized particles, which is a frequent source of annoyance with "pin-hole" burners.

FIG. 441.—The Dayton Burner, showing the Starter Box and Regulator in Position.

An interesting variation on the common type of steam carriage burner is presented in the device used on the Whitney carriage. This burner is made with the usual top and base plates, the air tubes being inserted and flanged over, as already described. Instead of the usual slits or punctures for the gas to pass through, each tube is perforated on each 90° of its circumference; thus making communication to the interior of the gas chamber within the flattened cylinder. A second tube is then inserted within the first, fitting closely, except for a slightly diminished circumference at about the level of the perforations just mentioned. The gas from the mixing chamber, entering these perforations, passes between the two tubes, and, mixing at the top of the tube with the air drawn through the draught tube, produces a very hot flame, as in the ordinary type of Bunsen gas burner. A similar effect is gained with several types of burner using a number of straight perforated tubes with air spaces between, thus ensuring plenty of air for combustion from both sides of the flame.

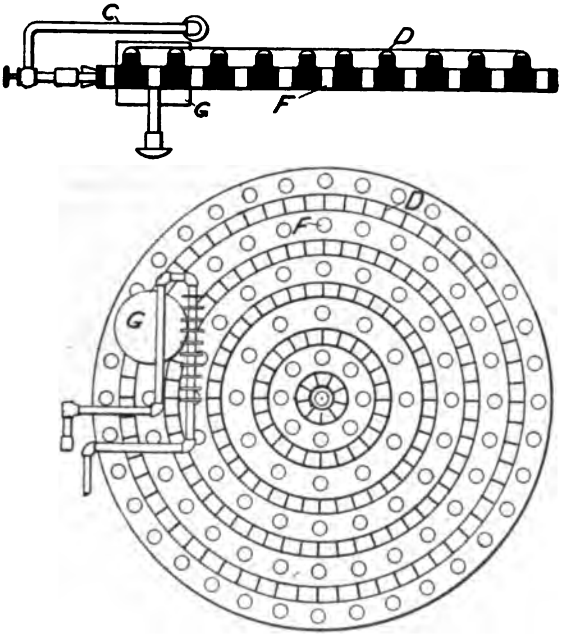


FIG. 442.—Plan and Sectional Elevation of the White Burner.

The White Gasoline Burner.—The burner used on the White carriage is also an interesting departure from the common types. As shown in the plan and sectional sketches, it consists of an upper, or face, plate of cast iron, having concentric corrugations, between which are the draught tubes, connecting the top and base plates, as in other burners. Instead, however, of the usual pin-holes or slits around the openings of the draught tubes, there are concentric rows of radially disposed slits across the raised corrugations on the face of the upper plate. The sketch shows

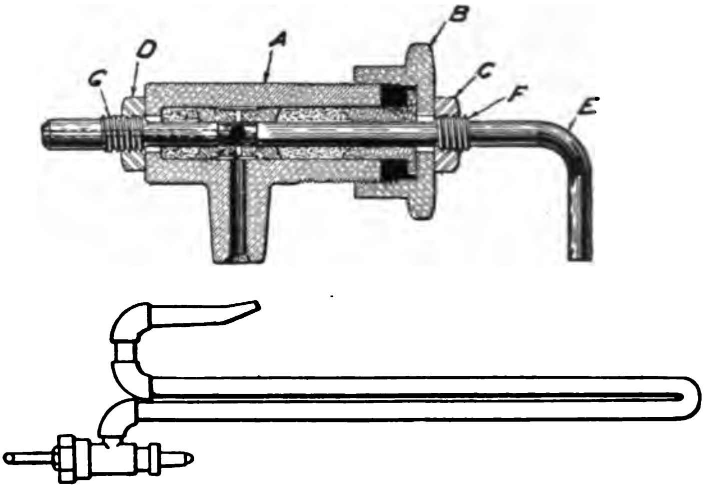


FIG. 443.—Usual pattern of "torch" head and starting "torch," used on several American steam carriages. The head parts are lettered as follows: A, body of head; B, threaded cap; C and D, nuts working on screws, F and G, on rod, E. Screw, G, gives attachment to the collar on the valve stem, as shown at B, in the succeeding figure.

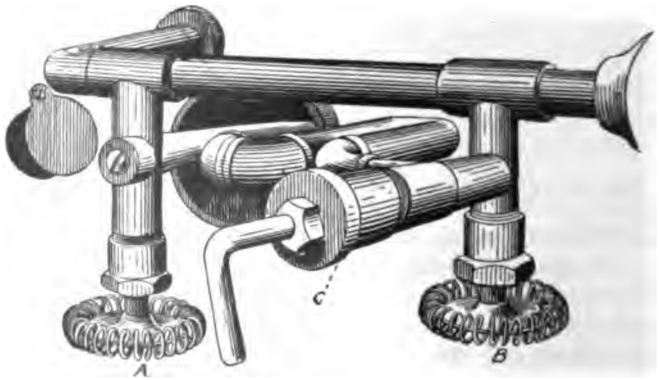


FIG. 444.—Showing the torch in position. By reference to Fig. 217, it may be readily understood that the head of the torch, C, is attached to a nipple on B by screw, G; the bent tube being thrust through a port in the burner casing so as to come directly over the fire; the nozzle entering the mixing tube by the side of the nozzle on the main valve, A.

these in larger number than on the burner in actual use, which, being about 14 inches in diameter, has the slits arranged at intervals of about ½ inch.

Obvious constructional and practical advantages inhere in this design, since: (*a*) The draught tubes, being separated from the flame, cannot be loosened by the heat. (*b*) Being arranged to either side of each circle of flame, sufficient oxygen is supplied to produce perfect combustion. (*c*) The construction is such that there is no danger of warping or deformation under heat.

The automatic thermostatic regulator, described above, is used with this burner. The incoming gasoline supply goes to the preliminary vaporizer, *C,* over the pilot burner, *G,* thence through the vaporizing tubes, and through the regulator, and into the mixing chamber, whence it emerges through the fire slits, *D, D.*

Methods of Starting the Fire: The "Torch."—There are several methods of starting the fire in gasoline carriage burners, each having been devised as an improvement in way of simplicity and ease of operation.

The most familiar method of starting the fire is by the use of a removable auxiliary vaporizer, or "torch," such as is used on the "Mobile," and several other well-known steam carriages. It consists, briefly, of a continuous iron tube bent double at the centre, as shown, and having a cock and screw head at one extreme and a tapering nozzle at the other. This instrument is held in the fire of an ordinary stove, or over a fire kindled with cotton waste saturated with gasoline, until it reaches a temperature usually described as a "sizzling heat," which is to say the point at which any moisture applied to its surface will occasion the familiar "sizzle," noted when water is dropped on a stove lid. It is a heat just below the point where iron begins to redden. Some authorities advise that the "torch" be heated to a "dull red," as that will give a better temperature, when it is inserted in the burner.

The "torch," having been heated, its double bent tube is inserted in an aperture in the burner casing, designed to receive it, the screw and valve end being attached at an aperture controlled by the pin valve and hand-wheel, *B,* in the sectional cut of the automatic regulator, and its nozzle being inserted in the same aperture as is penetrated by the nozzle controlled by the pin valve and hand-wheel, *A,* in the same figure. This done, the hand-wheel, *B*, is turned, so as to open the needle valve at the end of its stem, as far as is required; thus admitting liquid gasoline into the double bent tube of the torch through the screw and valve attachment. The result is that, passing through the heated tube, it is vaporized, and the burner is ignited by a match or paper lamp-lighter thrust through an aperture prepared for that purpose.

An Auxiliary Coil Starting Device.—The starter used with the "Dayton" burner, already described, is shown in an accompanying cut. There, as may be seen, a small box, called a "starter box," is attached at one side of the burner It contains a short coil of tubing, into which liquid gasoline may be admitted by opening the valve marked "starting valve." A few drops of liquid gasoline are then allowed to drip into the "starting cup," beneath the coil, and this, set on fire, will speedily generate sufficient gas to light the pilot burner, from which, in turn, the main burner may be kindled as soon as the vaporizing tubes are sufficiently heated. As soon as this point is reached the needle valve to the main burner, shown at the right hand of the starter box, is opened, admitting gas through the nozzle into the mixing tube. By closing this valve, the main fire may be shut off, as desired.

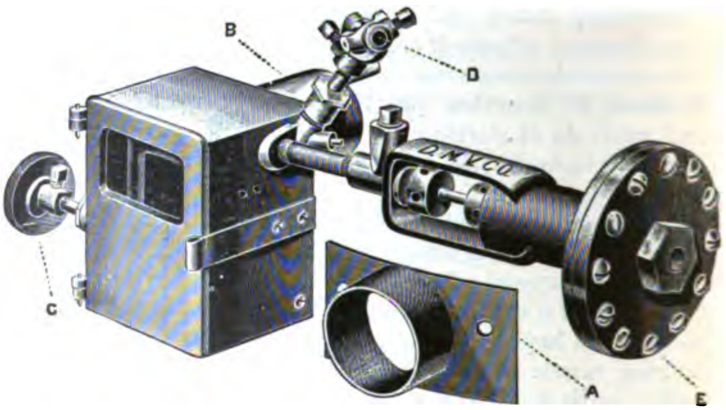


Fig. 445.—Starter Box and Diaphragm Regulator of the "Dayton" Burner. The parts are: A, segmental plate and collar at opening of the mixing tube; B, thimble on starter box containing supply pipe to the mixing tube and burner; C, starting valve; D, knuckle joint for connecting control valve to driver's seat; E, head-piece of the diaphragm regulator.

although the pilot light continues burning, until extinguished by shutting off its supply of gas, which is never modified in any way, being out of reach of the automatic regulator controlling the fuel feed to the main burner.

The Kelly Vaporizer and Burner.—The preliminary vaporizing device used on the Kelly burner is equally interesting in operation. A "generator" box, attached to the outside of the burner casing, encloses a portion of the tubing leading from the supply pipe and gasoline tank, and also attachments for the various valves. The bottom of this box contains a drip cup, and is arranged to open on a hinge, so as to allow of attaching an adjustable alcohol lamp, as shown in the accompanying cut. In order to begin the process of vaporizing the fuel previous to lighting the burner, the movable drip cup and bottom of case is opened out, as shown at *C* in the cut, and the alcohol lamp, *K*, is hung

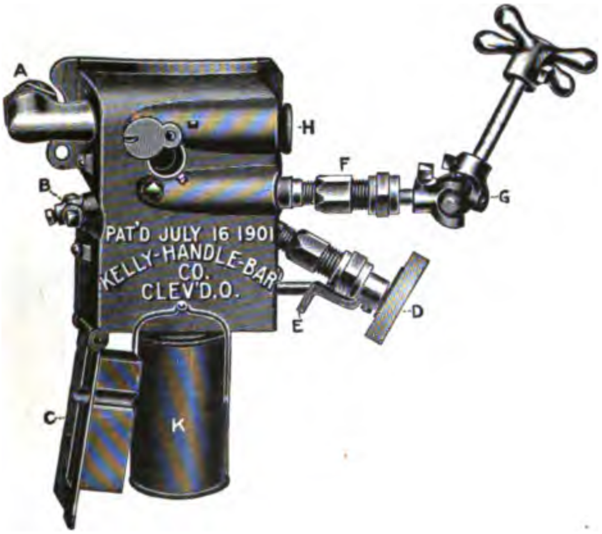


FIG. 446.—The Starter Box and Control Valve of the Kelly Burner. A, union joint to supply pipe; B, gas orifice leading direct to the main burner; C, drop drip cup and bottom of case; D, sub-flame valve; E, check on valve to prevent turning by vibrations of travel; F, packing nut on the main fire valve; G, knuckle joint to carry rod to seat; H, opening to screw on the diaphragm regulator; K, the alcohol lamp hung in position to start vaporizing and fire the burner.

beneath the opening. A flame is kindled in this lamp, and, after it has burned several minutes, the "sub-flame valve," *D*, is opened, and the lamp removed. At this point it is possible to ignite the vaporized gasoline at the opening of the "sub-flame valve," by applying a match through the small drop door shown near the top of the generator box. After the flame has burned about a minute more, the main fire valve may be opened, slowly at first, in order that the burner and supply pipes may be thoroughly heated. As soon as the burner is thoroughly started the small door at the base of the generator is closed. In case the alcohol lamp has been lost, the drip cup formed on the inner face of this door may be used for the preliminary vaporizing flame by partially opening it and igniting the contained gasoline with a match. Gasoline may also be burned in the lamp in case no alcohol can be obtained.

CHAPTER FORTY.

SIMPLE STEAM CARRIAGE ENGINES.

American Steam Carriage Engines.—In the particular construction of steam engines for use on motor road carriages there has been almost as much variety of design as in the other branches we have already noticed. We may say, however, that the typical engine for steam carriages, as constructed in America, is the two-cylinder, double-acting engine, reversible with the Stephenson link motion. The high perfection to which these engines have been brought in America enables the construction of very small motors, and the production of a high percentage of power. As a usual thing such engines work simple, but several excellent types of the American steam carriage, such as the McKay and the Stearns, are equipped with compound engines, which, however, may be run simple when the extra power is required, as, for instance, when ascending steep grades, or running through unusually heavy roads. A few steam carriages, notably the Reading carriage, are also equipped with single-acting multiple cylinder engines, which combine peculiarly ingenious devices for effecting reversal and controlling the valve

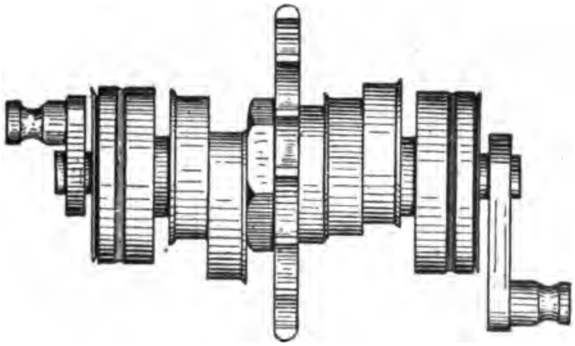


FIG. 447.—Crank Shaft of the "Locomobile" Steam Carriage, showing the cranks at both ends, the ball bearings and eccentrics, and the sprocket at the centre. Most steam carriage engines have similarly arranged crank shafts, although with several makes the entire mechanism is turned from one solid casting.

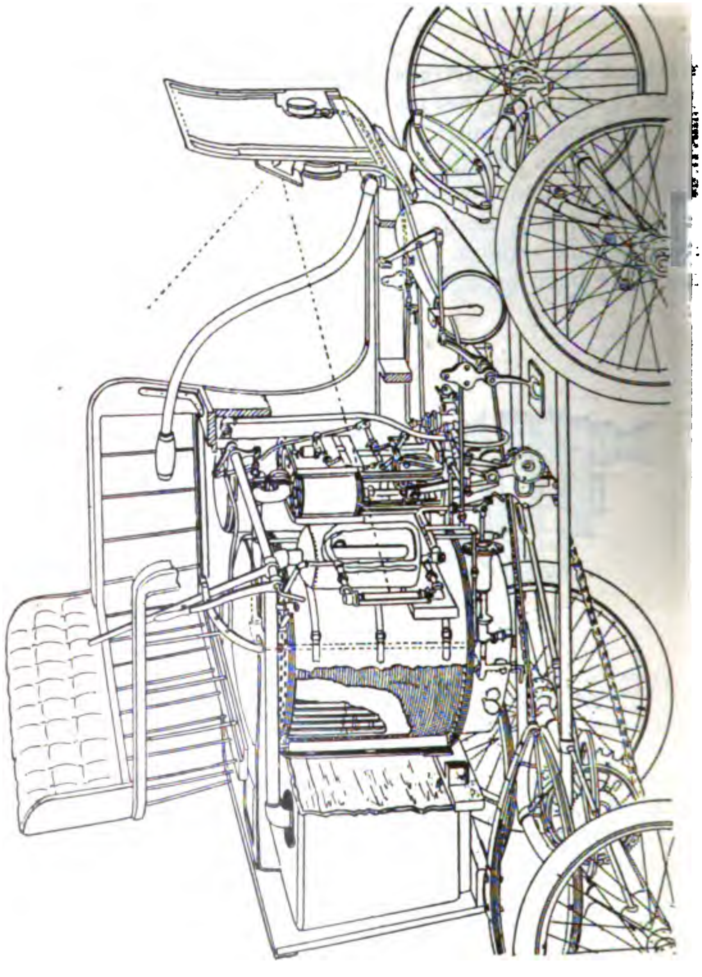
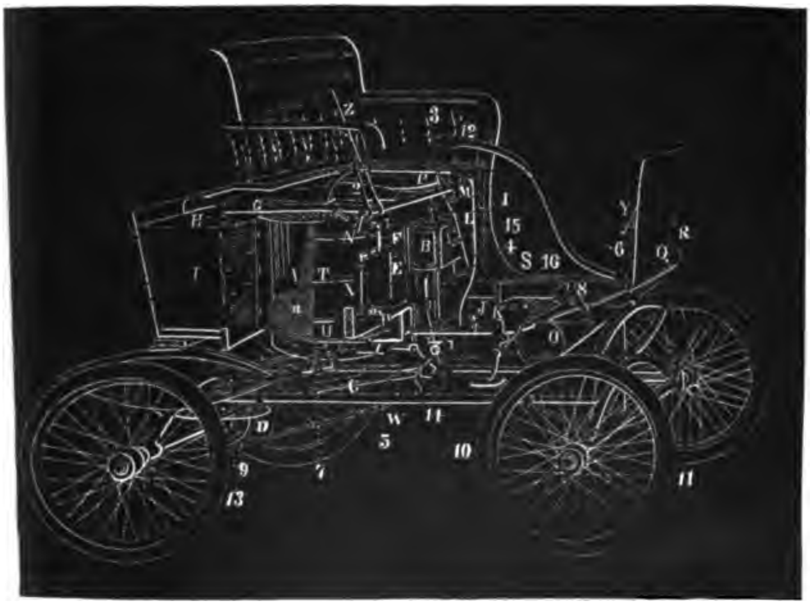


FIG. 448.—Part sectional view of the "Locomobile" Steam Carriage, showing machinery and parts in position.

gear. Single-acting steam engines, with from two to six cylinders, have also been brought to high perfection in Europe, being most familiar in the Gardner-Serpollet carriages.



SCIENTIFIC AMERICAN.

FIG. 449.—Diagram of the "Locomobile" Steam Carriage, showing parts in position. A is the boiler shell of copper; *a*, the winding of steel piano wire; B, the double cylinder engine; C, the adjustable strut, or distance rod; D, the compensating gear; E, pipe leading from engine to muffler, F, for exhaust steam; G, pipe leading from muffler to vent at H; I, the water supply tank; J, feed pump operated from the engine cross-head; K, cock in front of check valve on water supply pipe, for cutting off the supply from the tank; L, pipe leading from pump to the by-pass, M; N, lever for operating the by-pass; O, fuel supply tank; P, reserve air tank; Q, the dashboard; R, the air-pressure gauge; S, pipe leading from fuel tank to burner, through which gasoline is passed under air pressure; T, metal straps holding the lagging, U, around the boiler, A; V, the diaphragm fuel feed regulator, explained in connection with Fig. 207; W, pipe leading steam from boiler to diaphragm of the regulator; X, the water glass; Y, the mirror for reflecting the water glass; Z, starting lever. Other parts are: The crank arm on Z acting on the lever (1); the reversing lever (2); crank arms on the reversing lever (3 and 4); the pop safety valve set at 240 pounds (5); the steam pressure gauge (6); fuel valve to main burner (7); foot pedal (8) operating band brake (9); wire wheel spokes (10); pneumatic tire (11); steering handle (12); sprocket on rear axle (13); blow-off valve (14); oil feed cup on engine cylinders (15); pipe from air tank to fuel tank (16).

The "Locomobile" Carriage and Its Engine.—One of the most efficient among the American double-acting simple engines is that operating the "Locomobile" steam carriage, which has two cylinders of 2½ inches diameter by 4-inch stroke, and a total output of 4 to 5 horse-power, at between 300 and 400 revolutions per minute. It is equipped with the Stephenson link motion and "D" slide valves, and operates the boiler pump from the crosshead. The crank shaft of this engine, shown in the

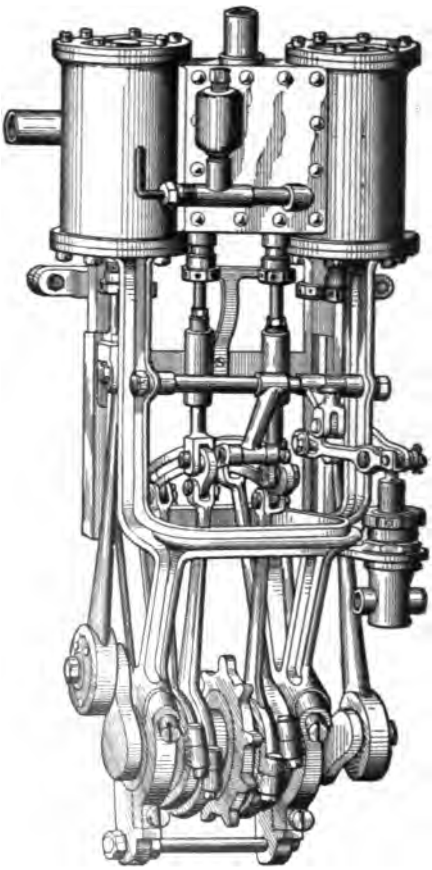


FIG. 450.—The "Locomobile" Steam Carriage Engine.

accompanying drawing, carries the sprocket at the centre, the eccentric drums on either side, and runs in enclosed ball races, with the cranks at either extremity. The cranks are fixed at 90 degrees. As seen from the accompanying figure of the engine, the cylinder and driving gear are hung on a heavy cast frame. This frame is bolted to a wooden crosspiece rigidly attached to the body frame of the carriage.

To the base of the frame is attached an adjustable strut, or distance rod, by which its relative position, as regards the rear axle, may be varied by a right-and-left threaded nut, or turnbuckle. By this device the slack of the chain may be taken up, and, to allow for the slight variation, thus necessitated, the steam pipe connection to the top of the steam chest is by a U-shaped pipe provided with "expansion joints."

The boiler used in this carriage has already been described

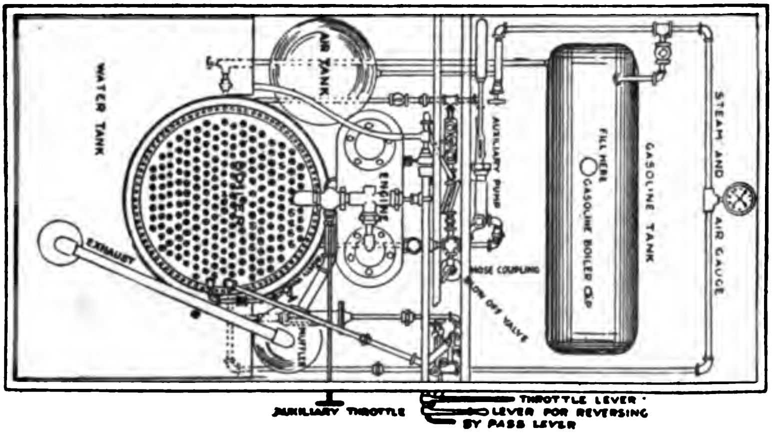


FIG. 451.—Plan Arrangement of the "Locomobile" Steam Carriage, showing position of the parts indicated in Fig. 245.

in connection with Fig. 144. It is supplied by a small plunger pump operated from the crosshead of the engine, drawing its water from the tank shown at the rear and either side of the boiler. On the runabout carriages of this make the water tank has a capacity of fifteen gallons. The water may be cut off by closing the cock, shown at *K* in the lettered diagram of this carriage, or may be returned to the tank by opening the by-pass valve, *M*, by the lever, *N*, at the driver's right hand. Up to the present time the manufacturers of this carriage have avoided the use of most automatic devices, other than the fuel regulator, as already described.

CHAPTER FORTY-ONE.

SINGLE-ACTING STEAM CARRIAGE ENGINES.

The Serpollet Single-Acting Engines.—In the effort to simplify, as far as possible, the construction and operation of steam vehicle motors, intended for use on light carriages, several inventors have contrived excellent types of single-acting engines. Among the advantages to be derived from the use of this type of motor, we may mention dispensing with the stuffing-box and several other constructions, which involves constant danger of wear and difficulty of repair. Among the best known single-acting steam engines may be mentioned those designed by Leon Serpollet, and used on the steam carriages manufactured by his firm. As constructed by him, the single-acting steam engine very much resembles some types of gasoline motors used on heavy vehicles, both as regards the cylinder and piston and operation of the valves. In an accompanying figure is shown an elevation, partly in section, of one of his horizontal double opposed cylinder engines. As may be seen there, the cylinders are open at the forward end, toward the crank space, in a manner very similar to that used on gasoline motors of the same pattern. The piston is of the trunk type, consisting of a somewhat elongated hollow cylinder, with the crank rod pivoted on the gudgeon pin somewhat less than midway in its length. The

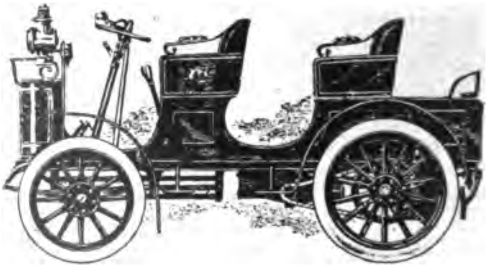


FIG. 452.—Gardner-Serpollet Steam Carriage built for King Edward VII. This carriage fairly represents the designs of Serpollet.

valves in this engine are of the familiar mushroom or poppet type, and are opened by a push rod positively operated from a cam shaft. This shaft is operated by a spur-wheel, which meshes with another spur of the same diameter, mounted on the crank-shaft, so that the two turn in even rotation. The exhaust valves are of precisely similar construction and are also positively operated from the same cam-shaft.

Such an engine as this has been constructed with from two to six cylinders, and as may be understood, gives about the same power effect as an engine of the ordinary design and same proportions of stroke, having from one to three cylinders. The cylinders operate on one plane, and are not offset, as in many opposed-cylinder gasoline motors, the danger of interference of the crank rods being prevented by constructing each of them to embrace only about one-third the circumference of the crank-pin, thus permitting a sufficient play to enable them to adapt their motion to the full dip of the crank. The crank ends of these rods are held in place by clamp brasses at either side. In

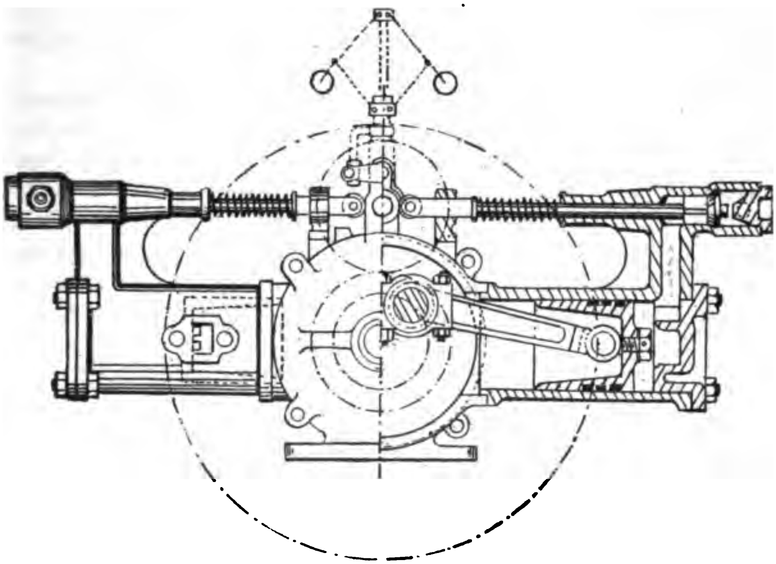


Fig. 453.—One Model of Serpollet Single-acting Two-cylinder Engine. As may be seen, this engine, with cam-actuated poppet valves, centrifugal governor for regulating the cam movement, and large fly wheel, closely resembles gas engines of the double-opposed cylinder type.

a diagonally arranged motor of the same description, the same end of non-interference is attained by forking the crank end of one of the crank-rods, and constructing the other single, so that the former may work over the latter on the crank-pin. As may be understood from the fact that the steam and exhaust valves are positively operated by a series of cams on a shaft, so that when the steam valve of one is open, its exhaust is closed, involving that the steam valve of the opposite cylinder is closed and its exhaust open. In order therefore to reverse the engine, it is necessary only to slide the row of cams on the square camshaft that carries them, so as to shift the positions and operation of the valves on the two cylinders.

All the Serpollet carriage engines of this description are supplied by the Serpollet flash generator, already described, the fuel and water being fed and regulated by a system of pumps and valves, already described. For driving an ordinary road carriage, seating two passengers, a two-cylinder motor is used, with a stroke and diameter each equal to about 2.55 inches, giving, with 700 revolutions a minute and a mean effective pressure of about 75 pounds, an approximate rating of 3 horse-power.

CHAPTER FORTY-TWO.

COMPOUND STEAM ENGINES.

Compound Steam Engines for Light Carriages.—Although many of the earliest types of the American steam carriage still use simple engines, several of the most excellent of the later patterns have adopted compound engines. The principal objection made by many authorities to the use of compound engines on steam road carriages of light weight is that with cylinders of average dimensions, working power of between 150 and 200 pounds, in the high pressure cylinder, and a cut-off generally between ½ and ¾ stroke, which has been found most economical under ordinary conditions, the low pressure cylinder would be doing little or no work, the whole strain of operation coming on the former, which would practically be working against a vacuum. On the other hand, with the final pressure of between 35 and 40 pounds, and the port clearances necessarily amounting to between 20 and 30 per cent., there is a considerable waste of steam, as well as excessive condensation. A well-known manufacturer of steam carriage engines states, that in order to obtain effective work from both cylinders of a compound engine, the high pressure cylinder must be made about one-half the size of the cylinder used in the simple engine. Then, he asserts, the mean pressure will range from 75 to 100 pounds in the usual running, with cut-off at ¾ stroke and the diameters of the two cylinders in ratio of 1 to 3, and the low pressure cylinder will do its share of the work, with the desired economy of power. The difficulty claimed with this arrangement is, that the total reserve power will then be only about one-half that of the simple engine, unless boiler steam can be admitted to both cylinders at any desired time while running, as well as in starting, and the back-pressure be eliminated by exhausting from both to atmosphere.

Another objection is that the efficient compound engines used in stationary power plants, on ships, and, to a certain extent in railroad locomotives, are operating constantly against a practically fixed load, which is not the case in steam carriage work.

FIG. 454.—Compound Engine of the Thornycroft Steam Wagon.

But this is not of such vital importance, since the average run of compound engines, designed for light road carriage use, may be run simple, whenever it is so desired, and the power may be varied with any well-made simple engine by shifting the point of cut-off. Thus, as is admitted by most experienced steam-carriage drivers, the throttle valve must be very constantly manipulated, in order to maintain anything like uniform speed on ordinary roads, whose surface conditions are ever changing. One important consideration, however, is that a compound engine, with two cylinders of different dimensions, involves considerable vibration, and consequent strain on the parts, such as is not experienced with a simple engine, whose cylinders are uniform as to size and power-output. Thus, when running compound, the small cylinder is exerting a power somewhat in excess of the larger one, and, when both are running with live steam, the larger one is powered two or three times higher than the smaller. Such an objection undoubtedly holds good for a given type of engine, but with the better designed American road carriages, equipped with compound engines, the vibration seems hardly more noticeable than with the easy-moving simple engine.

The Stearns Compound Engine.—The compound engine used on the Stearns steam carriage is one of the most typical and efficient of its class. The high pressure cylinder is 2½ inches in diameter, by 3½ inch stroke, and the low pressure cylinder 3 inches in diameter, by 3½ inch stroke. As is claimed, each develops 2¾ horse-power when running compound, and about double that when running simple. As shown in the accompanying diagram, it is built on the usual plan of the double-cylinder steam carriage engine, each cylinder being controlled by piston valves of the usual construction. The valve chest also contains inserts or liners, which increase the accuracy of the parts and admit of ready adjustment when the old liners are worn by use. Between the two valve chests and in connection with both, is the controller valve chamber, which also contains a piston valve, similar to that used in connection with the cylinders, except that it is larger in diameter and has double connections. The position of this control valve may be altered by a lever coming to the hand of the driver, so that at any time the operation of the engine may be shifted from simple to compound or from compound to simple. This control valve is bored from end to end, and has the usual angular recess on its outer surface, besides the internal port extending clear around the top, bringing into connection various passages leading from the control valve chest to the high and the low pressure valve chests and their exhaust ports. As shown in the illustration, the control valve stands at a point just above the ports which cut off the steam from the steam chests. Were it lowered, so that its top would be even with the bottom port on the high pressure cylinder side, the engine would run compound. In this position, therefore, the live steam from the boiler passes from the control valve chest through the port just cleared by the control valve, to the high pressure steam chest, being then distributed by the high pressure valve, as it alternates between the two ends of the cylinder. The high pressure valve being shown in a position where the lower end of the high pressure cylinder exhausts, the path of the steam leaving this end of the cylinder may be easily followed to the steam valve, through the exhaust passage, and the high pressure valve through the passage leading to the control valve chest. Thence, through the

FIG. 455.—Compound Engine of the Stearns Steam Carriage

internal port of the control valve, and through another passage leading to the low pressure valve chest, it is distributed alternately to both ends of the low pressure cylinder. As the high pressure piston is shown at one-half stroke, and as the two cranks are set at 90 degrees, the low pressure piston is in its extreme inner position; and the lower end of the cylinder is just beginning to exhaust. The steam exhausted from the low pressure cylinder flows through the port to the exhaust chamber surrounding the

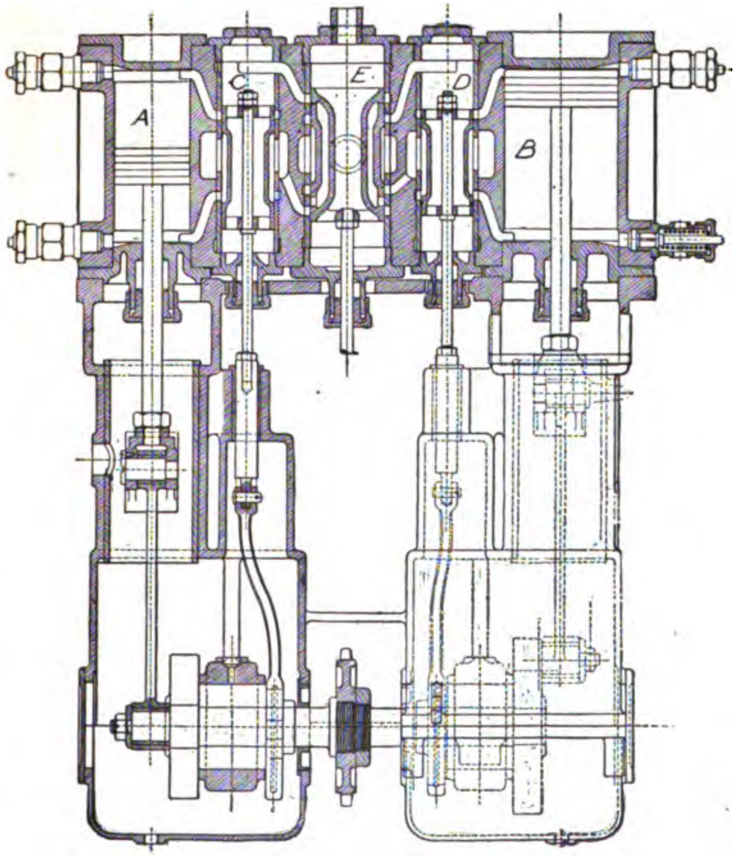


Fig. 456.—Section of the Stearns Compound Steam Carriage Engine. A is the high-pressure cylinder; B, the low-pressure cylinder; C and D, the steam valves operated by single eccentrics; E, the central control valve and chamber.

low pressure valve, and from there through the passage to the exhaust chamber surrounding the control valve, whence it is led to atmosphere.

If the control valve be raised until the passage shown in the drawing, as connecting the exhaust port of the high pressure cylinder with the internal port of the control valve, be uncovered, the operations of the exhaust and admission ports are reversed and the engine runs in the reverse direction. When the control valve is shifted until it uncovers the passage shown in the drawing, as connecting its internal port with the low pressure valve chest, live steam from the boiler will flow to both valve chests, and the engine will then work simple, thus providing increased power that may be required in an emergency, as when ascending a steep incline or passing over an unusually rough road. Further, by slightly varying the position of the control valve, the steam may also be throttled by this manner of working the engine. The exhaust ports of both high and low pressure cylinders being then in communication with the central exhaust port, both will, therefore, exhaust to atmosphere. As shown in practice, these simple acts of shifting the control valve, may be readily and rapidly acquired, thus enabling the operator to economize both fuel and water by regulating the power output to the requirements of travel. Its practical operation also demonstrates, when running simple, that the average American steam carriage is somewhat over-powered for the requirements of good roads and average speed, and that a large percentage of the steam, ordinarily wasted, may be used for effective work.

The Thornycroft Road Wagon and Compound Engine.—The practice of using compound engines on motor road carriages has been much more frequently adopted on heavy wagons and lorries than on light pleasure carriages. One of the best known makes of motor road wagons using compound engines is the Thornycroft, several parts of which have already been described. The engine used on the two and four ton wagons, manufactured under the Thornycroft patents in England and America, is a two-cylinder horizontal compound engine, having a 4 inch diameter for the high pressure cylinder and a 7 inch diameter for the low pressure, and a stroke of 5 inches. The steam valves are of the balanced cylindrical type and are operated by single

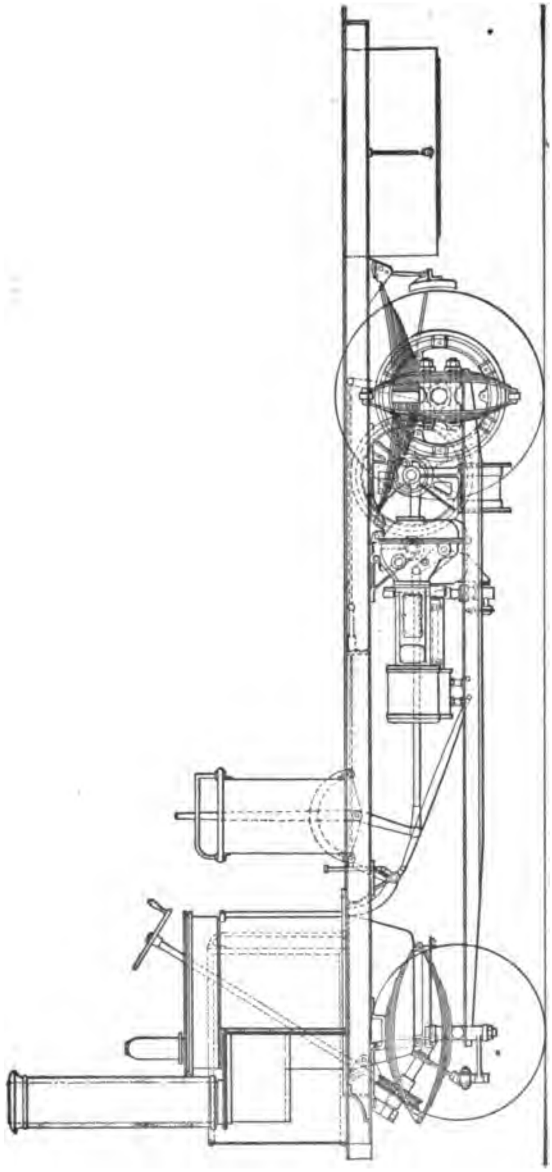


FIG. 457.—**Side Elevation of the Thornycroft Steel Wagon, showing engine and parts in position.**

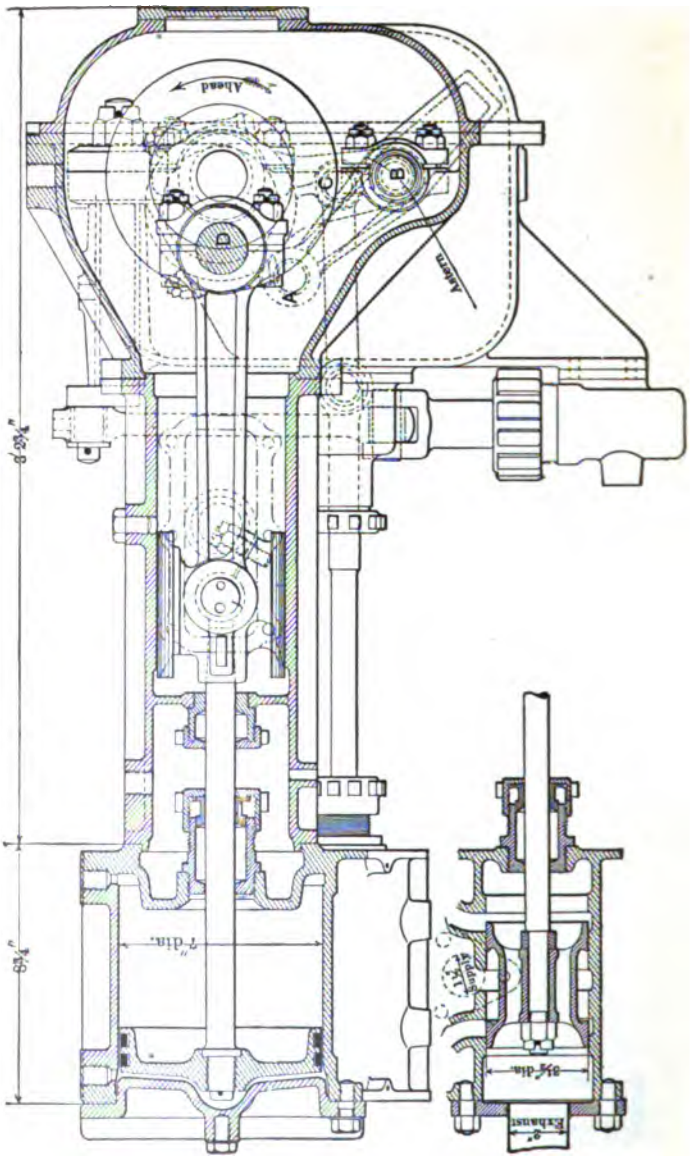


Fig. 458.—Sectional View of the Thornycroft Compound Steam Engine.

eccentric gear from the crank shaft. As shown in the sectional drawing of this engine, the eccentric carries an arm, *C*, which is connected to the valve rod by a link bar. It is also connected to the swinging link, *A B*, by which reversal may be effected. When this swinging link is in the position shown in the drawing, the wagon moves straight ahead; when it is brought downward, to the position marked "astern," the direction is reversed. The intermediate point, of course, has no effect on the movement of the valve. This device furnishes a simple and ready method of controlling the engine, and has the advantage of being less complicated than the ordinary link motion. An engine of the dimensions specified above can develop 20 brake horse-power at 440 revolutions and 35 brake horse-power at 770 revolutions, when the low speed gear is in use. This is an exceptionally high rating for an engine of this size; measuring only 3¼x2½x1½ feet, and weighing less than 500 pounds.

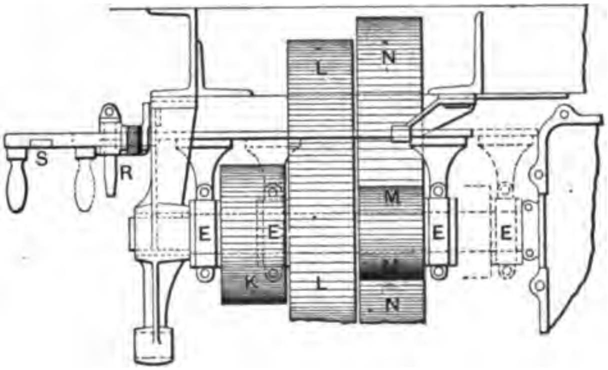


FIG. 159.—Change Speed Gear used on the Thornycroft Steam Wagon.

Contrary to the usual practice with steam road wagons, both light and heavy, the Thornycroft wagon has a system of change speed gears, somewhat on the pattern of those used in connection with gasoline motors. As shown in an accompanying figure, these gears, mounted on a counter-shaft, may be changed by shifting in the width of the wagon by means of a lever, *S*. When this lever is in the position indicated, the low speed gears, *M* and *N*, are meshed. When, however, it is moved to the right, as indicated by the dotted lines, the bearings, *E* and *E*, are also shifted as shown, bringing the gears, *K* and *L*, into engagement.

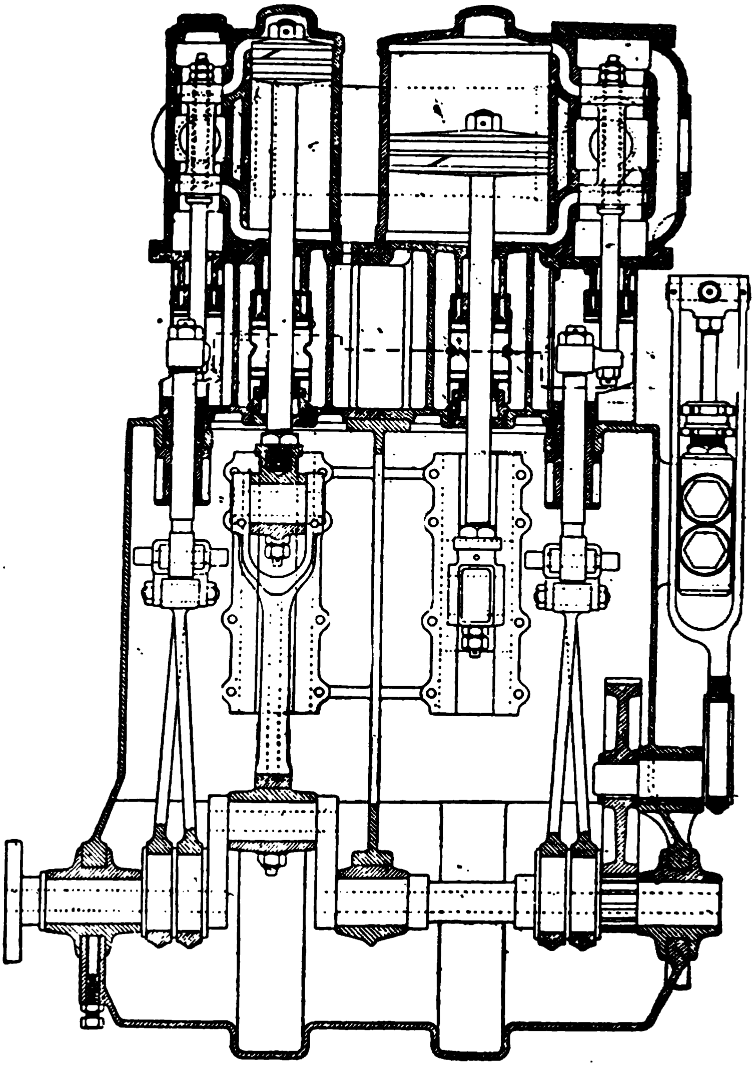


FIG. 460.—The "Lifu" Compound Steam Engine for heavy vehicle use. This section is drawn through the centre of the cylindrical steam chests, which, as in the Thornycroft engine (Fig. 273), are below and at the sides of the steam cylinders. The appearance of eccentricity in the attachment of the piston rods may thus be understood.

This gives the high speed forward. The operation of the wheels, which are hung on a loose rotating rear axle, as already explained on page 104, in connection with Figs. 89 and 90, affords an exceedingly elastic connection, and great tractive efficiency. The elevation of the wagon, showing the relative arrangement of the parts, is shown in an accompanying figure. The plan is given in Fig. 73 and a description of the water tube boiler on pages 190-193.

The "Lifu" Compound Steam Engine.—The compound steam engine used on the "Lifu" steam wagons is shown in section in an accompanying figure. It is of the cross-compound horizontal type, with reversing links, having cylinders of 3 inch and 6 inch diameters respectively, and a 5 inch stroke. The steam inlet of both cylinders is controlled by simple balanced piston valves, and as indicated in the drawing, the valve boxes are placed somewhat below the general level of the engine. When running compound the steam is exhausted from the high pressure cylinder into a receiver tube, which, as shown by dotted lines in the drawing, connects the two cylinders and their valve boxes from below. There is also an auxiliary valve as shown at the right hand of the low-pressure cylinder, by which live steam from the boiler may be admitted direct to the low-pressure cylinder, thus permitting both to run simple whenever occasion demands.

Among the special features of this engine may be mentioned a second pair of gland boxes run between the forward cylinder head and the guide bars, in order to prevent all leakage of condensed steam into the crank case, which is enclosed so as to allow the moving parts to run in oil. The main feed pump is worked from the crank-shaft, being geared direct to a single eccentric, which works on a small secondary shaft operated from the main shaft by spur-wheels. Attached to the strap of this single eccentric is a forked connecting rod which works on a crosshead attached to the rear of the pump. By this arrangement it is possible to reduce the speed of the pump, since the ratio of the two meshed spur-wheels is about 1 to 6. In addition to this pump, there is also an independent steam pump for use in case of emergency.

CHAPTER FORTY-THREE.

HINTS ON THE CARE AND OPERATION OF A GASOLINE VEHICLE.

Water and Gasoline Supply.—The first consideration previous to starting a motor carriage is to see that the water and gasoline tanks are properly filled; indeed, it is a good practice to make it a habit to test both tanks on each occasion of preparing for a run. Some motor carriages have glass gauge tubes fixed to the fuel and water tanks, so that the level of the liquids in both cases may be determined at a glance. In others it is a simple matter to test the level by inserting a stick in the filling hole and noting the height to which the liquid rises on it. This may be done with gasoline if the stick is withdrawn quickly and examined before evaporation takes place.

General Directions for Starting the Motor.—When all reasonable preparations have been made, and it is evident that the motor and running parts are in working order, the next important step is to open the cock leading from the gasoline tank to the carburetter, and also to close the sparking circuit by means of the designated switch, or plug, provided for that purpose. The spark should be set back to the full length of the quadrant.

Failure of the Motor to Operate.—In a large number of cases when the motor fails to start, or stops or slows down from no other assignable cause, it is probable that the trouble lies in some disarrangement of the electrical sparking circuit or attachments. If a jump-spark is used, it is probable that the plug has become short-circuited through either a deposit of carbonized particles between the sparking points, which defect frequently follows the use of too rich a fuel mixture, or else that the insulation has been broken down and that a path is provided for the electrical current between the two conducting portions of the plug. If the former defect has occurred, the sparking plug may be unscrewed from the combustion chamber and the condition may be readily detected. This carbon deposit may be readily removed by rubbing the points with a piece of light emery paper until the bright surface of the metal is again visible. Care should be taken, however, by non-practiced hands, lest the metal be unduly worn in the operation. The sparking points of a jump-spark plug should always be mounted at a fixed distance of not more than one twenty-fifth of an inch, which is approximately equal to the thickness of an average heavy business card. If, on the other hand, the plug has become disabled by a short-circuit through the body below the sparking points, it is practically useless, and it is unnecessary for the driver to attempt to repair the injury. The reason of this is that such a condition of short-circuiting is due to the fact that the insulation has been burned out, or that foreign substances have been deposited in such a manner as to leave a path for the electrical current.

Failure of the engine to operate properly may be readily traced to the sparking circuit by unscrewing the tap of the peep-hole, or the disconnecting inlet valve case, according to the kind of motor that is used, and observing the intensity and quality of the spark, if any occurs, by continuing to turn the crank used for starting the motor.

Troubles with the Ignition Circuit.—Troubles with the ignition circuit, however, may be due to derangements at some point other than the sparking plug, and before removing the plug and substituting a new one it is desirable to see that all the other parts of the circuit are in proper working condition. Among other things that should be carefully provided for, the driver should see that: (1) Insulation of the lead wires is perfect at all points and that short-circuiting does not occur through contact with any of the metal parts of the vehicle or motor; (2) the terminals of all lead wires should be tightly screwed under binding post; (3) the contact-breaking trembler should be adjusted so as to operate properly, which means that all screws and attachments should be kept securely tight; (4) the battery should be tested occasionally in order to ascertain whether it is giving the full amount of current. Most of the chemical batteries used in the sparking gas engines may be relied upon to give the required current for a certain definite period; therefore, unless some defect in circuit has caused unusual waste of electrical energy, or an unusually long continued operation of the vehicle has practically exhausted it for the time being, it is safe to conclude that the trouble is at some other point. A battery may be easily tested by the use of the ordinary pocket gauge, which may be obtained from any electrical supply house, and when it is desired to make a test the gauge may be readily connected to the terminals of the battery and will register the output with sufficient accuracy for all practical purposes. In making such a test, however, it is desirable to continue it no longer than is absolutely necessary to read the gauge record, since the operation means a short-circuiting of the battery, which will prove fatal to any chemical cell if long continued. Where chemical cells are used, it is a comparatively simple matter to carry several extra cells in the vehicle in order to be able to make substitution in case of suspected difficulty with the battery.

Starting the Carriage.—When the motor is running properly and the driver wishes to start the carriage, the first operation is to throw on the clutch with the speed adjusted to low gear; this is very essential in order that the start should not be too sudden, which would result in discomfort to the occupants of the carriage and strain on the parts. After the carriage has once fairly started, the second speed may be thrown in as soon as desired. It is very essential, however, particularly for an unskilled driver, to recognize the fact that with any variety of change speed gearing, the changing of speed ratios must always be preceded by throwing out the main clutch. In changing from a lower to a higher speed, it is important that the operation should be performed on as level a roadway as possible and should be consummated before the carriage has lost its momentum. On the other hand, in changing from a high speed to a lower one, it is exceedingly desirable, if not imperative, that the momentum of the carriage should be allowed to fall as near as possible to the desired speed before the new gear is thrown in. Hill-climbing is invariably performed with a low gear, but it is well to observe the rule that the higher speed should be used until the travel of the carriage has fallen considerably, and the motor shows signs of laboring; it is then the time to throw in the low speed, which relieves the motor of any undue strain, and enables the hill to be climbed without injury to the moving parts.

Working the Carriage on Down Grades.—In descending grades many drivers indulge in the sport of coasting, which is very delightful, but somewhat dangerous with heavy-weight cars, and an inexperienced driver should be particularly careful in performing this feat, since it has frequently happened that a heavy car has become unmanageable on a steep grade, the steering apparatus failing to act, with the result that a serious accident occurs. In coasting the clutch is thrown out and the carriage allowed to move down the grade under its own momentum. With carriages having a direct spur drive to the rear axle, like the light De Dions and some early American-made light phaetons, it is possible to leave the motor in gear with the driving connections and by interrupting the sparking circuit, allow it to act as a buffing brake to maintain the speed within safe limits. In coasting down a hill a driver should always observe the precaution of keeping his foot or hand, as the case may be, on the connections of the braking lever, in order that the speed of the carriage may be checked at any desired point. It is always well to keep the hand on the braking connections in any such position, until sufficient experience in running the carriage has been obtained to enable risks to be incurred with impunity.

In descending a very steep grade the operator should never allow his vehicle to attain a high speed. If the motor is left in gear with the sparking circuit interrupted, as already mentioned, the low gear of the speed changer should be used, but the retarding effect of the piston compression should be assisted by slight pressure upon the emergency brakes. If the brakes fail to work properly, in order to restrain the speed before it reaches an unmanageable point, the high gear should be thrown in, which will materially assist the effort of the brakes, unless the latter are completely disabled.

Turning Corners and Side Slipping.—There are several other conditions met with in ordinary travel which should be rigidly observed. The first of these relates to the necessary operations performed in turning corners. Any turns, except those of the longest radius, should be made on low gear. If a sudden turn is to be made, as in rounding a street corner, the best practice, when moving at a high speed straight ahead, is either to throw out the main clutch and allow the vehicle to turn with its own momentum, or to retard the spark by means of the properly designated connections to hand, in order that the carriage may not race around the corner, with the very probable result of incurring injury or accident, particularly on a wet or greasy street, where the wheels are liable to slip sideways, when turning at the high speed, with the result in frequent instances of seriously damaging the running gear. Also, if too short a turn is made, the carriage will have a tendency to swing bodily, and may even go so far as to turn completely around in an opposite direction. This will not, however, cause a well-built vehicle to capsize, owing to the properly adjusted centre of gravity, but, particularly with heavy cars, it is exceedingly liable to break an axle or rend a tire. Should this accident occur under these conditions, the main clutch should be immediately thrown out, and the steering wheels held strongly in the direction in which it is desired to travel. On no account should the brakes be applied except as a last resort. Even then, it is a questionable procedure, and one liable to disarrange the steering, rather than check the undesired motion.

Common Causes of Failure to Operate.—In addition to the causes already enumerated for the failure of the motor to start or run properly, we may mention several other conditions which will produce the same result. These are: (1) an imperfect combustion, owing to a bad fuel mixture; (2) imperfect compression, owing to leaks in the cylinder or to defective valves; (3) dirt or water in the carburetter.

Troubles with the Sparking Apparatus.—In case the driver suspects that the failure of the motor to operate is due to some trouble with the sparking apparatus, producing imperfect combustion, he may readily verify his suspicions by advancing the spark. As stated by a well-known authority on motor vehicle operation: "If the motor does not miss with the spark advanced, you may rest assured that the trembler needs adjustment; if, on the other hand, varying the position of the spark lever does not alter the condition of things, then there must be either a wire loose, or the gasoline mixture must be at fault. To adjust the mixture move the gas lever back and forth. If the engine sticks, it means, you may rest assured, that there is a wire loose or a short-circuit somewhere. Go over the wiring carefully and see that the same is properly fastened to the sparking plug and to the battery terminals. If the trouble still continues, there must be a short-circuit." This short-circuiting is probably due to breaking down of the insulation in the sparking plug or to a collection of carbonaceous material between the sparking points.

Troubles Due to Breakage or Wear.—In case the motor suddenly ceases to run, there are three common causes to which the trouble may be attributed: (1) Breakage of the exhaust valve; (2) sticking or breaking of the inlet valve; (3) short-circuiting of the sparking plug. The trouble due to either of the first two of these causes may be readily discovered by turning the starting handle, and finding no resistance or compression, such as should normally be encountered.

In case the exhaust valve should be found broken, it is necessary to insert a new valve in the seat, being careful to see that all reciprocating parts are properly adjusted and of the right length to interact. The sticking of the inlet valve may be caused by excessive heat or a catching of the spring, although either of these troubles is rare. If the valve or its spindle be broken, the only thing to be done is to replace it.

Causes of Imperfect Combustion.—There are several causes to which imperfect combustion may be attributed: (1) the valve may be pitted or clogged; (2) a leak may have occurred around the thread of the sparking plug; (3) a compression tap may be loose or leaking; (4) the piston rings may be clogged or stuffed; (5) the piston rings may work around, so that the spaces between their ends get in line; (6) the gasket of the sparking plug may be broken; (7) the inlet valve spring may be too weak, which fault accounts for an occasional popping noise in the carburetter.

The first difficulty may be overcome by grinding the valve, which, however, is an operation just as well left to skilled machinists.

Any leak that may be discovered around the thread of the sparking plug may be readily remedied by screwing the plug home. Troubles with the piston rings may be remedied by removing the piston from the cylinder occasionally and thoroughly cleaning it. Where the rings are found to work around the cylinder, the piston must be taken out and the rings placed in their proper relative positions. Any trouble with the spring of the inlet valve may be remedied by substituting a new spring.

The matter of dirt or water in the carburetter is a serious one in motor vehicle management. Water in the carburetter necessarily results from vaporizing of the gasoline. Since this liquid always contains certain portions of water, it is necessary to periodically drain the carburetter and remove it, as well as any other waste materials that may happen to be present.

Non-Freezing Water Jacket Solutions.—According to popular opinion, largely borne out in practice, it is difficult to operate a gasoline vehicle in winter time, owing to the freezing of the jacket water, or to excessive cooling of the cylinder. In this belief several manufacturers of vehicles propelled by air-cooled motors advertise their respective products as "The only serviceable winter vehicle." While it is undoubtedly difficult to obtain good results from a gasoline vehicle in attempting to start in cold weather, it is possible to largely neutralize the difficulties due to the freezing of the jacket water by mixing certain chemicals in the water. As already stated, various authorities recommend a solution of equal parts, by weight, of water and glycerine; others, a saturated solution of chemically pure calcium chloride mixed with equal parts of water, by measure. As already stated on page 369, any motorist attempting to use the latter solution should carefully avoid substituting the so-called chloride of lime for the desired calcium chloride. Another solution, which is recommended by other authorities, should consist of a mixture of water and glycerine, the latter being about 30 per cent. of the former by weight, and adding to this mixture two parts, by weight, of carbonate of soda. This liquid should be entirely drawn off and removed once a month.

Another trouble encountered in running a gasoline vehicle in cold weather is the difficulty of properly vaporizing the fuel. This condition may be largely neutralized by properly heating the carburetter in the manner provided, as we have seen in a number of typical instances. At all times heating materially assists the process of vaporizing.

CHAPTER FOURTY-FOUR

GASOLINE MOTOR CYCLES.

Gasoline Motor Cycles.—While there appears to be no very definite limit to the size and power of heavy and high-powered motor cars, beyond the point at which greater increase involves greater liability to wear and disablement of metal structures and tires, it seems that a serviceable vehicle may not be produced below a certain size and weight. There are various reasons for this, among which may be mentioned the difficulty of producing a structure at once sufficiently light and sufficiently strong to fill the requirements in a small vehicle. Again, it is very difficult, if not quite impossible, to include on such a machine, particularly on a bicycle, the desirable and necessary regulating and controlling devices required with any type of motor. The latter restriction holds since the rider of a motor bicycle is too fully occupied in maintaining his balance, and in guiding his machine through the intricacies of traveled highways and over the difficulties of rough roads, to have much attention to spare for the manipulation of apparatus requiring the exercise of either strength or judgment. Nevertheless, there seems to be a strong sentiment in the public mind that a light motor vehicle is the ideal for ordinary service; the demand for such is constant, and several firms in America are doing a large business in manufacturing motor cycles, especially bicycles, exclusively. The many grave practical difficulties in the way of success seem to example the high perfection to which the science and art of motor construction has been brought.

It may be interesting to note that the motor cycle is the pioneer in nearly every department of automobile construction, since the earliest modern examples of both steam and gasoline motor were equipped to propel such vehicles. Thus, as we have seen, Daimler's first high-speed gasoline motor was arranged to propel a bicycle, while Serpollet made the preliminary trials of his "flash" generator and single-acting steam engine on a tricycle of reasonable lightness. One or two ingenious inventors have produced electrically propelled bicycles, but, as must be obvious on reflection, such a machine can be no more than a curiosity; the weight of the batteries quickly limiting its range of travel, and the low efficiency of a small sized motor still further limiting its serviceability. At the present day the gasoline cycle is the only one that is attempted or demanded.

Requirements of a Motor Cycle.—According to experience in the matter, a motor cycle must be propelled by an air-cooled motor, preferably of rather low speed and of somewhat higher power rating than is actually required for the load to be carried. The reasons for both conditions are readily discoverable, since, having dispensed with the water-cooling and circulating system for sake of lightness and compactness, it is desirable to avoid such causes of overheating as unusually high speeds, and such low power as would cause the engine to labor under ordinary loads. Some bicycles have been constructed for racing purposes, with an advertised speed of 60 miles per hour and over, several of them having been equipped with a motor guaranteed to develop six horse-power, a rating far in excess of demands for carrying one person over an even roadway. At best, such machines are bulky and heavy, out of all proportion to convenience of handling or for ordinary service. Even with some machines designed for ordinary road service, and having an extreme speed limit of more than 25 or 30 miles per hour, the motor used is guaranteed to develop 2, and even 3 horse-power at between 1,200 and 1,500 revolutions per minute—speeds seldom attempted.

Regulating Attachments on Bicycles.—The motor bicycles manufactured in America use jump spark ignition, almost without exception. Few of them also have any regulating devices other than levers for varying the time of the spark and the opening of the valves—thus modifying the speed—and a cut-out switch located conveniently on the handle bars, for the purpose of stopping the motor. Adjusting the mixture of varying the time of the spark are the typical means provided for changing the speed. It is obviously impracticable to include such change-speed gears as are used on heavy vehicles and even on some tricycles, since the rider would be quite unable to operate such with safety, certainty, and convenience.

One excellent make of American motor bicycle has dispensed with the spark advancing apparatus, and varies the speed solely by interrupting the sparking circuit. A published description of this machine sets forth the system, as follows: "This cycle will run at a speed of from 5 to 25 miles an hour at the rider's discretion, and is under perfect control all the time. The instant the switch plug is pressed down the power is off, and at the same instant the compression in the engine acts as a brake on the rear wheel, which with the application of the brake on the front wheel, brings the machine to a stop as quickly as is possible, without a sudden stop. The timing of the spark can always be maintained by the adjustment of the screw without removing any parts of the motor.

"By the elimination of the advance spark mechanism this company claims that the machine has been much simplified. They claim they have demonstrated that a stationary spark is a perfect method, and the speed is regulated by the amount of gas fed to the engine. The rider controls his speed without removing his hands from the bars. A slight pressure of the thumb on the switch plug interrupts the electric current and shuts off the power instantly, a pressure of the index finger on the other end of the switch plug again completes the electric circuit and throws on the power. This enables him to increase or slacken his speed by pressing a button."

One of the things to be most avoided in motor bicycling is skidding, which is obviously much more dangerous than with foot propelled machines. A well-known English authority writes as follows on this point, illustrating the usefulness of certain constructions:

"It is generally known that an exhaust valve lifter is indispensable in this connection; but a very delicate carburetter which does not fail to give mild explosions, when the throttle is nearly closed, and which, in conjunction with mechanical valves, will keep the engine running 'dead slow,' is a useful safeguard against skidding. The next safeguard is a flexible drive. Advantage in this direction will be derived from having the flywheels much larger without being heavier. The jerks will be diminished and as it is the beginning of a slip that must be avoided, every trifle counts. Also, if these larger flywheels were to rotate in the opposite direction to the road wheels, then gyrostatic action would assist the rider in keeping vertical instead of acting in the opposite sense, as they do now." Exactly how his "gyrostatic action" could be obtained our authority does not specify, although the principles laid down seem to possess some element of truth.

One or two of the earlier types of motor bicycles, driving by belt direct from the motor shaft, had two separate pulleys—a large and a small one—attached on either face of the rear wheel, thus enabling the adjustment of speed before starting the vehicle, by belting in either one or the other. It is obvious, however, that, with a direct belt connection and a single reduction, it is far more convenient to regulate the speed and power output of the motor than to rely upon any form of variable gearing.

Arrangement of the Motor.—In the arrangement of the motor on a bicycle there has been a wide diversity of design. In some makes it has been supported on the back stays, between the pedal bearing and the rear wheel; in one make, on an extension of the back stays to rear of the wheel; in several makes it is supported against, or forms a part of the rear or saddle tube member of the "dimond" frame. The favorite position with most machines at the present time is on the forward member of the frame, in front of the pedal bearing, or on a tube arranged beneath, and suitably trussed to hold the weight.

The Transmission.—The method of driving is practically always by belt from a small pulley on the motor shaft to one of much larger diameter on the hub of the rear wheel. Most bicycles also have chains from the sprocket on the pedal bearing to another on the rear wheel, for use in starting or in case of disablement of the motor, and arranged to be thrown out by some form of ratchet or "coaster brake," as soon as the wheel is turned by the motor, thus having the pedals stationary in travel. The belts used for this purpose are generally twisted rawhide, and the length may be regulated, either by adjustable jockey pulleys or by unhooking the two ends and twisting or untwisting the strand to suit requirements. The use of hide belts is determined mostly by considerations of durability and safety, since the best-made chains are liable to snap at high speed, with the result, on a motor bicycle, of disabling the rear wheel, or of whipping up violently against the rider. A hide belt could break under similar conditions without dangerous consequences.

Apart from the considerations just specified, the belt drive is the only really effective method of economical power transmission.

One or two bicycles, notably the Wolfmuller and Holder machines, have had two or four-cylinder motor direct connected to cranks on the rear axle. Another had the motor hung upon the axle, which it turned through an internal reduction gear. Both these arrangements, however, involve the disadvantage of losing power for the doubtful end of increasing speed, and have been entirely abandoned by modern constructors.

The Auxiliary Apparatus.—The other essential parts of a motor bicycle are the carburetter and gasoline tank, the battery, the induction coil and the oiling apparatus, all of which, from the necessary limitations of construction, are made as compact as possible. Several bicycles have used a combination of gasoline tank and carburetter, as in the De Dion cycles, the whole apparatus being included between the four tubes of the diamond frame above the pedal bearing; the motor being fed through a special mixing valve. The favorite apparatus at the present time seems to be some form of float-feed sprayer operating to draw the supply from the tank located conveniently under the upper member of the frame or over the rear wheel. One or two bicycles at least use simple mixing valves of the general type already described under the head of the James valve. With either sprayers or mixing valves the prime desideratum is the possibility of throttling or of regulating, as the only available means of controlling the speed of the vehicle. The battery consists generally of two or three dry cells in a suitable box, no case being at hand in which a magneto or dynamo was seriously attempted as a source of current. The ignition circuit in most machines corresponds in general features with the De Dion and other secondary spark arrangements already described, including an induction coil of standard pattern, and generally also, a condenser.

The lubricating apparatus is, of course, important, especially for supplying the cylinder and engine bearings, and in the majority of modern bicycles consists of an adjustable oil cup with sight-feed attachment. The feed is thus rendered automatic, except for periodical regulations.

The Framework and Wheels.—The framework and wheels of motor bicycles are, of course, stronger and heavier than in foot-propelled machines. The tubes are made with thicker walls, and the joints are more securely reinforced. In several makes the end of security is further assured by struts and trusses, particularly at the fork on the steering post and at the place where the motor is hung. The diamond frame is practically universal, although several of the earlier types—notably the Wolfmuller and Lawson—used the drop frame. In the Holden bicycle the frame consisted of a single tube, joined to the steering post in front and bent downward to carry the drive wheel in a fork at the rear. The back stays were extended forward to hold the motor and other apparatus, and were further supported from the main tube by a dropping tubular member at front and rear. The pedals in this machine were geared to the forward wheel, as in old-fashioned velocipedes.

Jar-Absorbing Devices.—One great disadvantage in motor cycle construction is the practical difficulty of arranging any form of spring or cushion device to take the vibration of the motor. Several makes of machines include some spring arrangement in the saddlepost for easing the rider, but the framework must be built to endure the vibration of travel on rough roads, and at all speeds. The wear and strain, as may thus be seen, is immense. The only way to neutralize this element, moreover, is to provide the motor with extra heavy flywheels, in order to equalize the movement as far as possible. One excellent type of high-powered, high-speed machine, which has won exceptional records in a number of tests and races, has an extra large flywheel (between 18 and 21 inches, according to power), and the claims are that this "keeps the motor steady and does away with the heavy vibration in some high-powered machines." For machines intended for ordinary speeds such great additional weight is hardly necessary.

Brakes for Motor Cycles.—The question of brakes is an important one with motor bicycles and cannot be setlled off-hand without some consideration of conditions. The principal difficulty involved in using a shoe brake of ordinary bicycle design on the forward wheel is that the sudden stop would result in even worse consequences—owing to higher speeds and greater weights—than the foot-propelled machine. There are also a number of constructional and practical difficulties involved in the attempt to use a positive brake on the rear wheel. In the majority of machines, therefore, the front wheel brake is omitted, and the braking of the rear wheel largely relegated to the compression of the motor, after the interruption of the sparking current. Several makes of bicycle, however, are now equipped with a type of friction roller brake on the forward wheel, consisting of two small rubber rollers, whose axes are set at a wide angle, so that their peripheries brush against either side of the tire, when pressure is exerted on the hand lever. The advantage of such a device is that, while the motion of the machine is effectually checked, the stop is not so sudden as to result in disastrous consequences to rider or motor.

The construction of a motor bicycle precludes the possibility of closely observing the operation of the parts in the course of ordinary travel. It is desirable, therefore, as has been indicated by several authorities, to have a stand of such shape that the machine may be hung free of the ground and set in motion, in order to afford opportunity to watch the motion and note any unevenness that may occur. The principal troubles to be diagnosed in this manner are those relating to the action of the sparking circuit, although it is frequently necessary to employ such means of discovering troubles with the moving parts.

Motor Tricycles and Quadricycles.—Although the bicycle is the most familiar form of motor cycle, the tricycle and quadricycle are occasionally seen, and hence demand some brief description. The primary distinction between a cycle and any other type of motor vehicle seems to be that the former is provided with a saddle and is started—or may on occasion be propelled—by pedals. A tricycle, then, is a vehicle of this description having two rear wheels and one forward wheel, and a quadricycle, one provided with four wheels, two front and two rear. The most important distinction between the two types is that the quadricycle has a forward axle with two wheels—generally also carrying a seat for an extra passenger instead of the single forward wheel of the tricycle; both types being steered by handle bars from the driver's saddle. In fact, very many quadricycles are merely "converted" tricycles, and almost any tricycle may be changed into a quadricycle by substituting the two-wheeled fore-carriage for the single steer wheel.

Speed Gear Tricycles.—Owing to the different style of frame, enabling such cycles to stand alone, also to permit of the ready and certain manipulation of positive gearing, it is possible to include speed-changing attachments, generally giving two forward speeds, but no reverse. A differential gear is also necessary on the rear axle. Since the drive axle of most tricycles is at least four feet in length, there is sufficient room for hanging the motor and all other necessary apparatus—the battery, coil, and gasoline tank between the rear wheels. Unless the change gear is arranged to be thrown in or out, no clutch is provided. In several motor tricycles the speed is controlled solely by throttling the motor or varying the spark, thus involving that the motor is always in gear, to act either as a driving power or brake. Shoe brakes have also been used on the tires of tricycles, but this construction is not so common as a band on the differential drum.

With the motor constantly in gear the only method of overcoming its resistance, when it is necessary to drive by the pedals is to remove the sparking plug or loosen the spur pinion on the main shaft. The former operation is, or course, the easier, and, on the whole, the more effective; the effect being to neutralize the compression resistance by allowing air to circulate freely in the combustion chamber. Many cycles are provided with a special exhaust valve lift to keep the valve open when the motor is not needed, as when descending hills, or when it is necessary to use the pedals. The first object is also attained by the use of the compression tap on the head of the cylinder, either device operating to prevent the drawing-in of fuel charge and to do away with the resisting effect of cylinder compression. Should it be desirable to utilize the braking effect of the piston, the cylinder may be closed and allowed to operate, minus the sparking circuit.

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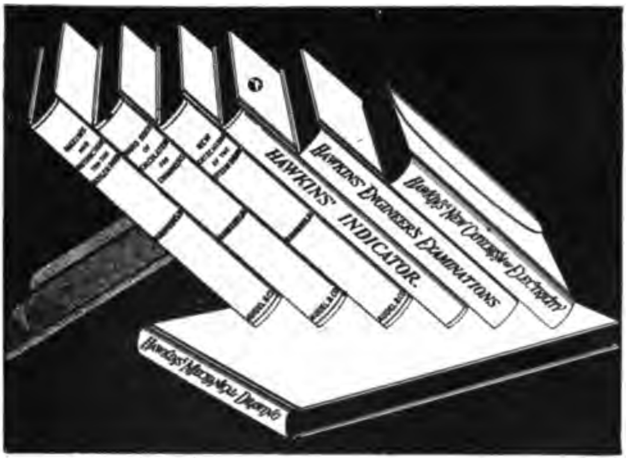
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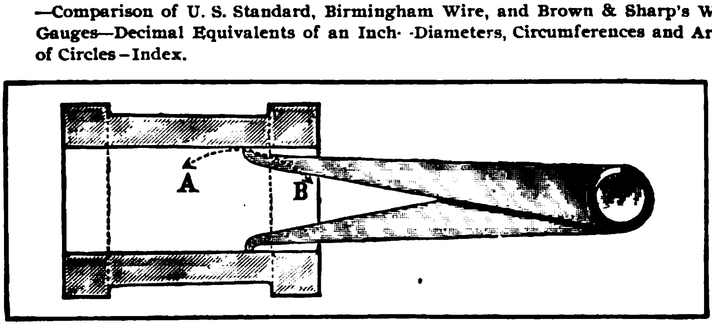

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