Plate I — CROSS-SECTIONAL DIAGRAM OF AN AMERICAN FOUR-CYLINDER TOURING CAR.

1. Divided front seat for chauffeur.
2. Throttle lever.
3. Steering wheel.
4. Steering pillar.
5. Brake or clutch lever.
6. Spark coil.
7. Spark coil vibrator.
8. Gravity feed gasoline tank.
11. Piston.
13. Compression chamber.
15. Spark plug.
16. Relief cock.
17. Exhaust valve.
18. Manifold.
19. Intake pipe.
20. Exhaust pipe.
22. Water circulating pipe.
23. Water circulating pipe.
24. Oil pump gear.
25. Radiator cap.
27. Front spring support.
28. Air cooling fan.
29. Driving chain for fan.
30. Starting crank.
31. Water pump.
32. Forward spring support.
33. Commutator.
34. Forward spring.
35. Tubular front axle.
36. Spoke.
37. Fender.
38. Rim.
39. Pneumatic tire.
40. Oil governor actuating pump.
41. Tubular sub-frame of engine.
42. Oil governor piston.
43. Reservoir oil chamber.
44. Parallel rod end.
45. Steering rod.
46. Cam actuating the exhaust valve.
47. Cam actuating the inlet valve.
48. Sliding bearing for cam shaft.
49. Connecting rod end.
50. Connecting rod.
51. Crank.
52. Crank shaft of engine.
53. Fly-wheel.
54. Expansion clutch.
55. Ball bearing for transmission shaft.
56. Planetary transmission.
57. Transmission brake drum.
58. Universal joint.
59. Exhaust pipe.
60. Brake rod.
61. Pressure feed pipe for gasoline.
62. Driving shaft.
63. Muffler.
64. Universal joint.
65. Rear side spring.
66. Bevel gear driving pinion.
67. Differential pinion shaft.
68. Differential pinion.
69. Differential housing.
70. Main gasoline tank.
71. Rear spring support.
72. Pressed steel side frame.
73. Swinging filler for gasoline tank.
74. Wooden frame of body.
75. Upholstering.
76. Upholstering frame.
77. Aluminum body.

78. Tonneau.
79. Side entrance door.
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 CAR-
RIAGES DRIVEN BY STEAM, GASOLINE AND ELECTRICITY.

THEO. AUDEL & COMPANY
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PREFACE.

Since the publication of the first edition of this book the motor vehicle has passed out of the experimental stage and become a practical reality. That it is now a permanent factor in the world of mechanics, in the domain of travel and recreation, and, latterly also, in commercial life, cannot for a moment be questioned. Already the profession of chauffeur, or automobile driver, has taken rank among skilled callings, affording a new and profitable field of effort. The demand for information of a practical character is insistent. This demand the present revised edition attempts to meet.

The motor vehicle is a singularly complex machine. Its construction and operation involve the consideration of an extensive range of facts in several widely separated departments of mechanical knowledge. The study of its construction and operation is a liberal education in itself. It claims a broad territory.

In order to answer every question that must occur to the practical automobilist, one must produce a whole library of books, rather than a single volume of convenient size. Virtually all such questions may be forestalled, however, by clear explanations of the principles governing the design and construction of the machine, and the most conspicuous situations involved in its operation. It must be said, to the credit of both designer and operator, that questions, perplexities and accidents are far fewer at the present time than several years
PREFACE.

ago. This is due to the general dissemination of knowledge of a practical character, also to the fact that the public has learned to consider the motor vehicle seriously, and award it the attention it deserves.

To the vast realm of motordom the present volume essays to discharge the function of a general introduction; a convenient guide book to the intricacies that must inevitably be encountered; a summary of the facts and principles that it is necessary to understand. As far as possible, the presentation of subjects has been determined by consideration of the needs of the man behind the wheel. Irrelevant matters have been eliminated, and attention has been guided toward present conditions, to the exclusion of all that is experimental and obsolete.

Honest criticism and suggestions would be genuinely appreciated by both the author and the publishers, who would esteem it an assistance in the direction of adequately dealing with a subject that is of great interest and still greater importance at the present time.

For kind assistance in the preparation of this new edition the author begs to render thanks to Mr. Charles E. Duryea; to Mr. E. W. Wright; to several leading authorities and manufacturers who have cheerfully furnished information, as acknowledged in the text; to a number of readers of older editions, who have made intelligent suggestions, and asked even more suggestive questions; and to the reading public, whose generous appreciation has encouraged him to attempt improvement on his former efforts.
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**Ready Reference Index**
CHAPTER ONE.

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

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*Fig. 1.*—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 ascendancy 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.

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. 3.**—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.

**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
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. 7—Hancock's Wedge Drive Wheel, showing wedge spokes and triangular driving lugs at the nave.

Fig. 8—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

![Diagram of Church's Three-wheel Coach (1833)](image)

Fig. 9.—Church’s Three-wheel Coach (1833), drawn from an old woodcut, showing forward spring wheel mounted on the steering pivot.

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.
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 al-

Fig. 10.—James’ Coach (1829), the “first really practical steam carriage built.” Drawn from an old wood cut.

lowing 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
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, as shown in Fig. 9, "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 TWO.

THE MAKE-UP OF A MOTOR CARRIAGE.

Modern Motor Vehicles.—Like other achievements of modern science and industry, motor road vehicles represent long series of brilliant inventions and improvements in several directions. As now constructed they are of three varieties, according to the motive power employed: those propelled by steam, those propelled by explosive engines, using gasoline or some other spirit, those propelled by electric motors. Considerable has been done in the direction of producing efficient compressed air motors, which have been applied to the propulsion of heavy trucks and street railway cars, but for ordinary 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 devices actually used in the construction and operation of motor carriages.

Conditions of Automobile Construction.—In one way the automobile has a history very like that of the railway carriage. At first 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 ordinary road wagons, several of which were coupled together, so as to be drawn along a grooved tramway. Later, with the introduction of flanged wheels and heavier constructions, several carriage bodies were mounted on one running truck, 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 adoption of the American passenger coach, did the day of real progress and comfortable travel begin. In similar fashion many of the greatest constructional problems of automobiles may be most readily solved, both for the designer and the operator, in recognizing the fact that they resemble horse carriages in no other respect than that both have similarly appearing bodies, mounted on four-wheel frames, and run on ordinary highways.

**Essential Elements of an Automobile.**—While in this age of the world it is impossible to assert that any device is perfected, or that any has reached a finality, it is admissible to assume, for practical purposes, that recognized standards of construction are permanent. Undoubtedly, the automobile of the future will possess many features now unsuspected, but it is with the automobile of to-day that we have to do. We will take up the essential features in turn, therefore, describing their construction and explaining their uses. These may be summed, as follows:

1. The power developed by a motor carried on the running gear is applied to the rear wheels, or to a rotating shaft to which they are secured.

2. The two driven wheels must be so arranged as to rotate separately, or at different speeds, as in turning corners. For this reason, the compensation or balance gear is an essential element.

3. The two forward or steering wheels, studded to pivots at either end of a rigid axle-tree, must be arranged to assume different angles in the act of turning, in order that the steering may be positive and certain.

4. The body of the vehicle must be set relatively low, or the wheel-base, the length between forward and rear wheel-centres, must be relatively long, in order to obtain the best effects in traction, steering and safety.
5. The springs must be of such strength and flexibility as to neutralize vibration, absorb jars and compensate any unevenness in the roadway.

6. The distance between the motor and the driven wheels must be fixed by adjustable radius rods, or reaches, in order that the drive may not be interrupted by the vibrations of travel.

7. The wheels must be shod with pneumatic, or other forms of tires, of sufficient resiliency to protect the machinery, running gear and passengers from the jars, otherwise inevitable at high speeds on ordinary highways.

8. Positive and powerful brakes must be provided, in order to secure effective checking of motion, whenever required.

9. All parts must move with as little friction as possible, in order to save power for traction. For this reason, ball or roller bearings are generally used on all rotating shafts of motor carriages.

10. Convenient and efficient means for ready and generous lubrication of moving parts is a constant necessity.

11. Balance of parts and stable constructions are required to reduce wear and friction.

12. Simplicity of structure, ease of handling and repair. These are the prime requisites of the best automobile.

13. All working parts must be of sufficient size, weight and strength to endure the jars of travel, and to be serviceable under all conditions. There may be some advantages in the light constructions, formerly supposed to be essential, but present-day practice recognizes the evident fact that strength and durability are the more important considerations.
CHAPTER THREE.

COMPENSATION AND COMPENSATING DEVICES.

Automobile Driving and Compensation.—The power of the motor is applied either to the centre-divided rotating rear axle, or to a rotating jack-shaft parallel to it, thence by chain and sprocket to the two wheels, turning loose on a dead rear axle. In both cases the drive is through a device known as the differential or compensating gear. 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 after the turn is completed, 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. 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 or jack-shaft, must always be the same in both directions, even though one wheel be stationary.

Compensation and Balancing.—For example, the device shown in Fig. 11 is an excellent specimen of a differential or compensating gear that is not also a balance gear. As may be seen, it consists of a large internal gear wheel, C, within which and rotating about the same axis is a smaller external gear or spur wheel, B,—the two engaging the spur pinions, A, A, as shown. The large internal gear turns on the axle of one wheel, the smaller or spur wheel on the opposite one, and power is applied through the pinions hung on radii of the sprocket. The
result was that the power-driven pinions 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. This device was formerly used on foot-propelled tricycles, and is perfectly suitable for a two-track machine of this description, in which the steering wheel is set directly ahead of one of the drivers, so as to progress on the same track.

Fig. 11.—A form of Differential Gear formerly used on Tricycles. The studs of the pinions, A, A, 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.

Automobile Balance Gears.—The most familiar form of balance gear for compensating the drive wheels of motor carriages is the bevel. 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 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, at which time the wheels tend to move with different speeds, the resistance of the wheel nearer the centre, on which the turn is made, tending to make it turn more slowly than the other, as anyone may readily observe, these pinions begin rotating on their own axes. Thus, while allowing the pivot wheel to slow up or remain stationary, as conditions may require, they continue to urge forward the other at the usual 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.