CHAPTER LXXVII

ELECTRIC VEHICLES

The term *electric vehicle*, is generally applied to a great variety of either passenger or freight carrying machines which are propelled by electric energy supplied usually from storage batteries, and in some cases from dynamos direct connected to gas engines; the latter type, however, does not include gas electric combinations used on some electric railroads.

The principal types of electric vehicle which are commercially successful at the present time are:

1. Electric automobiles, represented by various types of roadster, coupe, phæton, cab, etc., suitable for the use of physicians, business men and others, in city service.
2. Electric trucks and vans for moving merchandise, and for delivering purposes.
3. Gasoline-electric trucks, which represent an attempt to overcome the lack of flexibility of internal combustion engine by combining it with a dynamo and storage battery.

Electricity as a Motive Power.—Vehicles propelled by electric motors, whose energy is derived from secondary batteries, are preferred by some 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 fact that the storage battery must be periodically recharged from some primary electrical source, which fact greatly reduces their sphere of efficient operation.

Since electric vehicles are not the prevailing type, charging stations are in some localities few and far between which would make it impossible under these conditions to make an extended tour from the base of supplies. This difficulty cannot be overcome by carrying an extra battery since the additional weight would curtail the speed and carrying power of the vehicle.

It is impracticable to propel a vehicle by a battery of primary cell, since such a battery of sufficient power would have little, if any, advantage in point of endurance over secondary cells, and when once exhausted must be entirely replaced.

Light Electric Vehicles.—These are of various types, such as roadsters, victorias, phætons, runabouts and coupes, and are

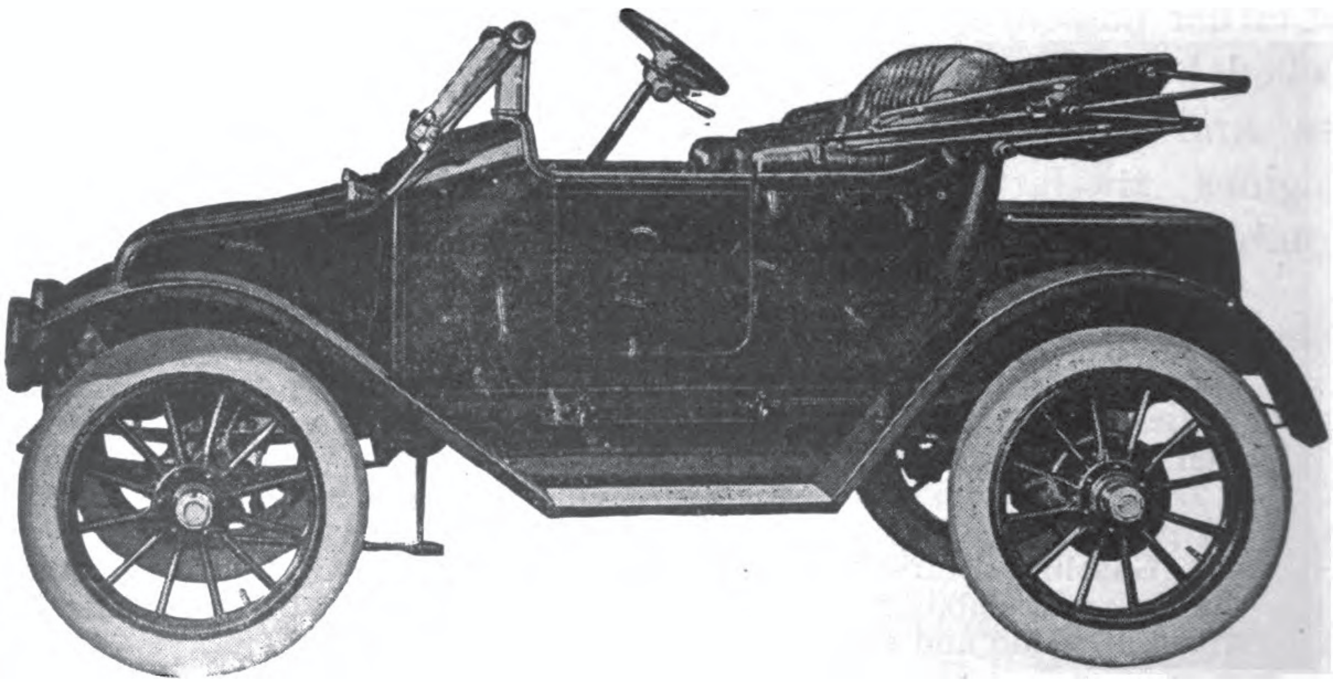


FIG. 4,058.—Baker electric roadster. The general specifications are as follows: frame, pressed steel; wheel base, 88 ins.; tread, 50 ins.; steering mechanism, two types, one with wheel steer, the other with lever steer; controller, continuous torque type, six speeds forward and three reverse; springs, semi-elliptic and full elliptic rear; battery, 34 cells, 13 MV thin plate Exide, standard; tires, 32×4 special electric pneumatic front and rear or 34×4 cushion front and rear; brakes, two sets of internal expanding on rear wheels, operated independently by two foot pedals; body aluminum, with side doors, open top, nickel and black metal finishings throughout; painting, body black, blue, green, or maroon panels, striping to match; upholstery, blue, green, or maroon leathers, or imported broadcloths, standard; fenders, full skirted metal curved fenders; equipment, two head lamps, two side lamps, tail lamp, side and storm curtains; volt ammeter and shaft odometer, full kit of tools, special adjustable clear vision wind shield, electric horn.

equipped with batteries which have a capacity ranging from 75 to 100 miles per charge, with controller arrangements for providing speeds varying from 6 to 25 miles per hour. In these cases the number of cell in each battery may vary from 10 to 30 according to the make and number of plate in each cell. The number of plate in each cell may vary to suit special conditions.

Electric Trucks for City Service.—Under certain traffic conditions and surface requirements, the superior mobility of the gasoline engine truck effects a saving in drivers sufficient to compensate for the higher maintenance charges, but when the number

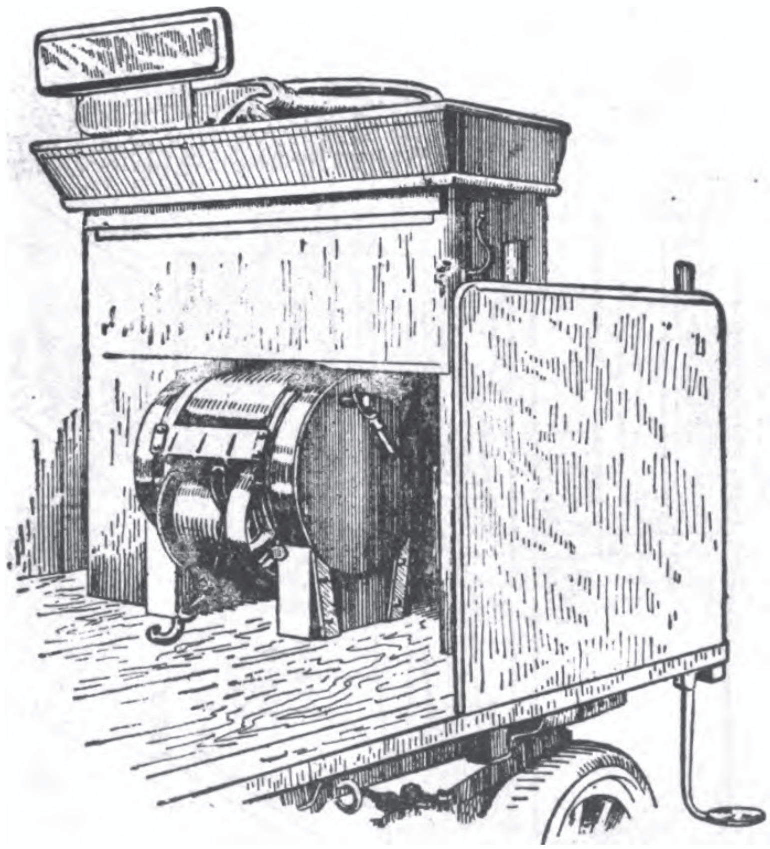


FIG. 4,059.—View of front portion of electric truck showing electric winch which provides mechanical means for loading or unloading, consequently reducing the time necessary for this performance, especially in the case of bulky and heavy articles, thus in some instances increasing the total utility of the machine and operator.

of active truck is the same in each case, the electric truck is sometimes the more economical.

The gasoline engine truck has the advantage in all classes of service requiring a greater mileage than that which is conveniently obtainable with the electric truck, but the greater portion of city delivery service is well within the limits of the safe operative mileage radius of the electric truck built at the present time.

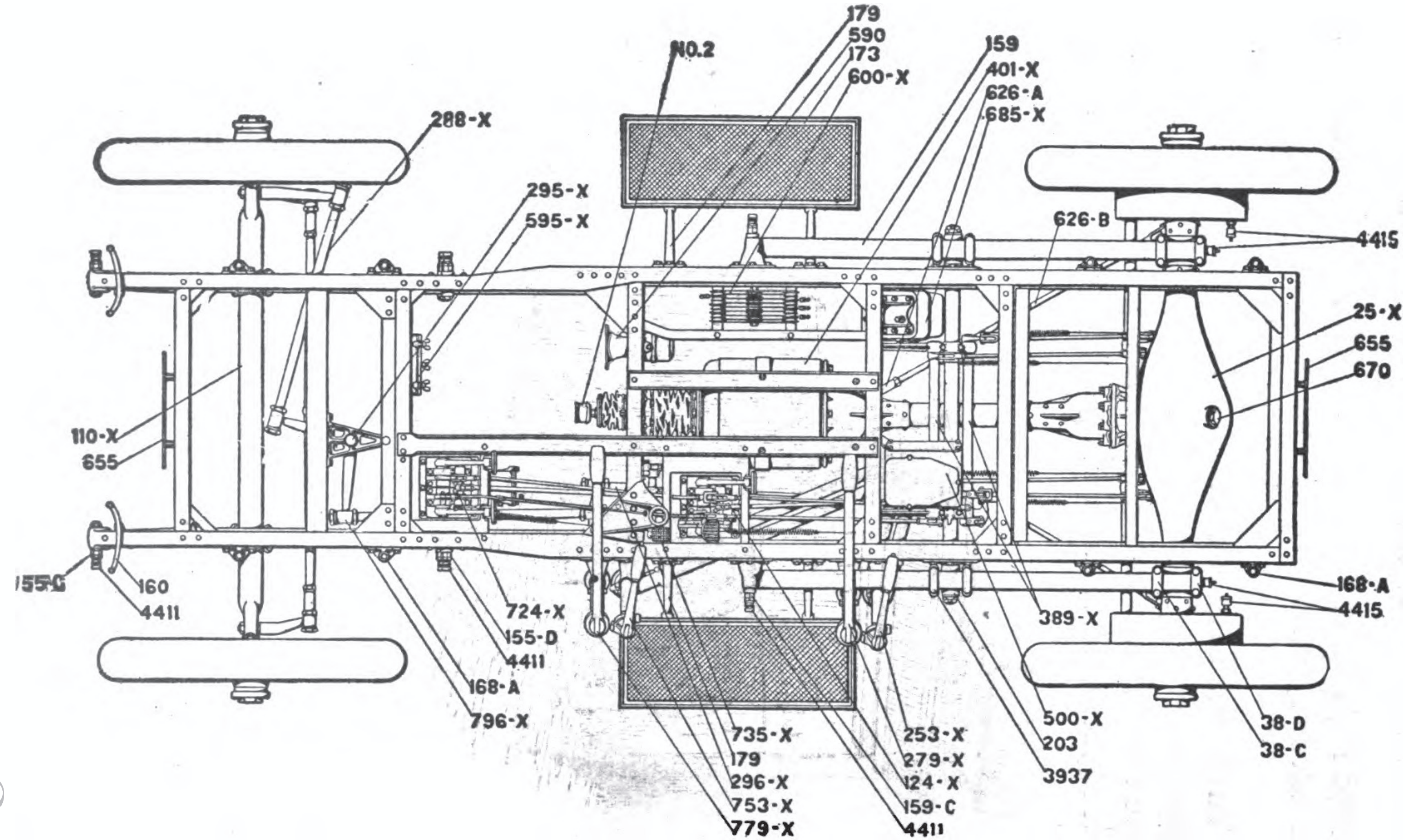


Fig. 4,060.—Plan view of Baker electric chassis. **The** parts are: 25-X, **rear axle**; **38-C, rear** spring yoke front; 38-D, rear spring **yoke rear**; **110-X**, front axle; 124-X, front levers, **rear**; 155-C, front spring bolt, front; 155-D, front spring bolt, rear; 159, rear **spring**; **159-C**, rear spring bolt; 160, head lamp **bracket**; 168, A, fender bracket; 173, step pad; 179, step bracket; 203, rear spring **seat, center**; 253-X, rear control mast; 279-X, **steering** mast, rear; 288-X, lower steering rod, bell crank to spindle; 295-X, bell **crank**; **296-X**, lower steering rod, mast to mast; **389-X**, brake shaft; 401-X, motor; 500-X, controller; 590, horn; 595-X, fuse **box**; **600-X**, resistance; 626-A, brace rod clevis; **626-B**, brace rod; 655, license bracket; 670, oil inlet; 685-X, contactor; **724-X, foot levers**, front; 735-X, interlock; 753-X, **front co**ntrol mast; 779-X, steering mast, front; 796-X, lower steering rod, **mast to bell crank**; 3,937, rear spring clip; **4,411, 4,415**, No. 2 grease cups.

Gasoline-Electric Vehicles.—The principal disadvantage of the gas engine for self-propelled vehicles is its lack of flexibility; while on the other hand, the principal disadvantage of the electric vehicle operated by means of storage batteries is its lack of mobility. It is evident that the short coming in each case can be overcome only by combining the gas engine with a dynamo connected to a storage battery, for supplying the power required by the electric motors.

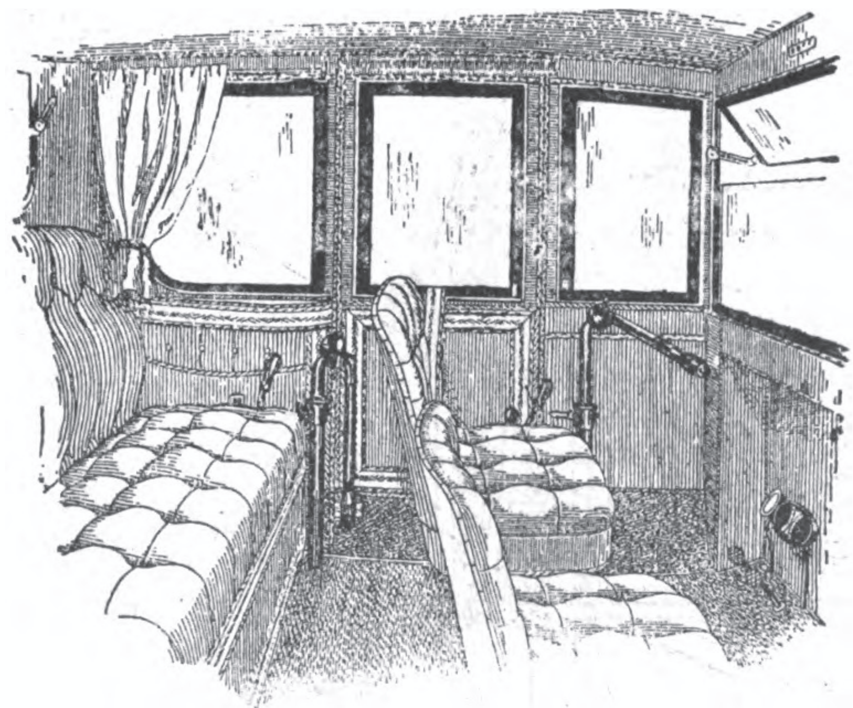


Fig. 4,061.—Interior Waverly front and rear drive electric brougham. The seating arrangement of this type of electric duplicates that of the Waverly front drive four with the addition of separate steering and controlling levers, and a separate set of brake pedal at the left of the rear seat. The car in this way gains the advantage of dual driving systems, a feature sometimes desired.

Such a combination will operate at practically constant speed at all loads, as the dynamo with the storage battery serves to furnish the necessary overload, or consumes that portion of the energy which is not needed. Furthermore, the transmission will be entirely electrical and will possess the simplicity and flexibility of electric control; while the use of a motor will allow the attainment of various speeds by series-parallel combinations.

Vehicles of this type are built in the form of omnibuses, surface cars and trucks for city service and freight and passenger cars for interurban railway service. The arrangement appears better adapted to the latter service, than for propelling pleasure vehicles.

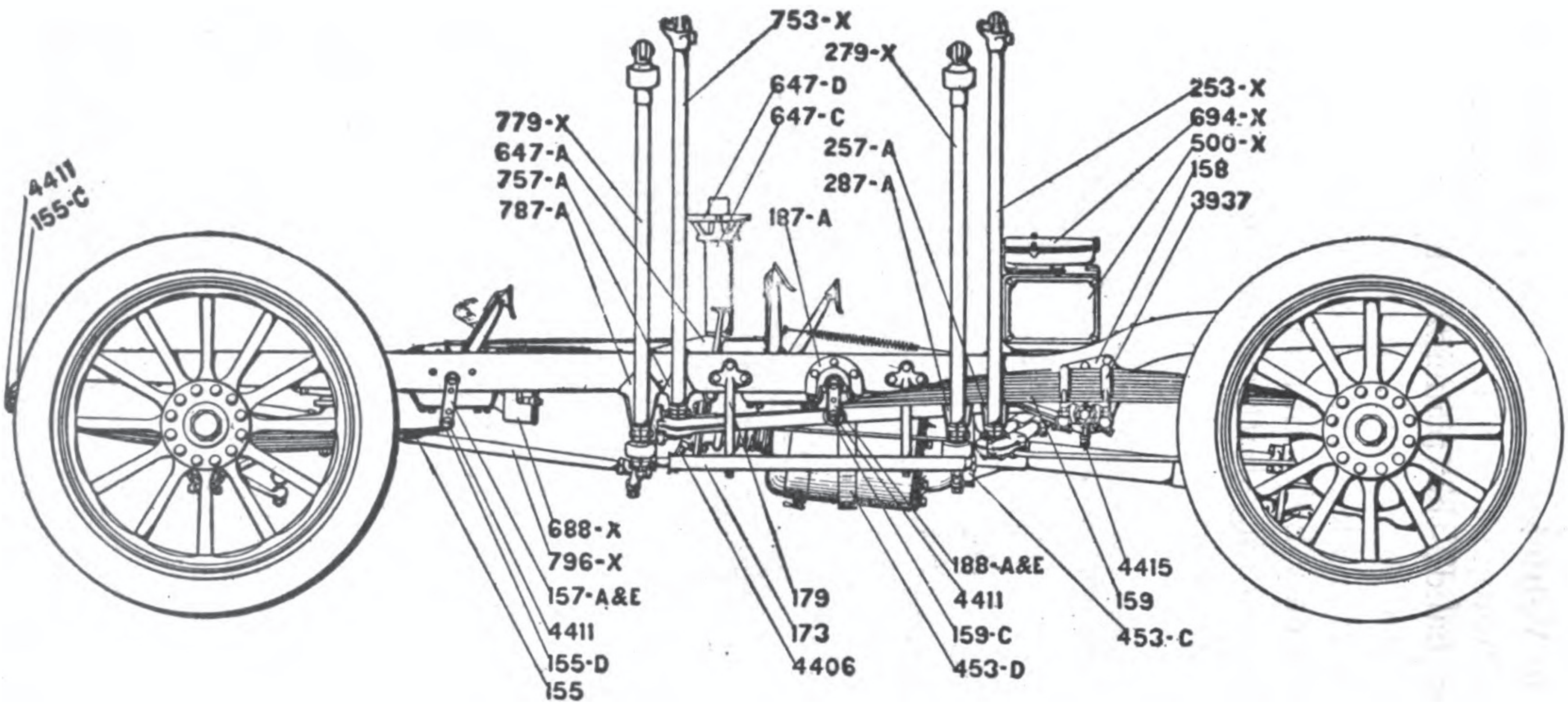
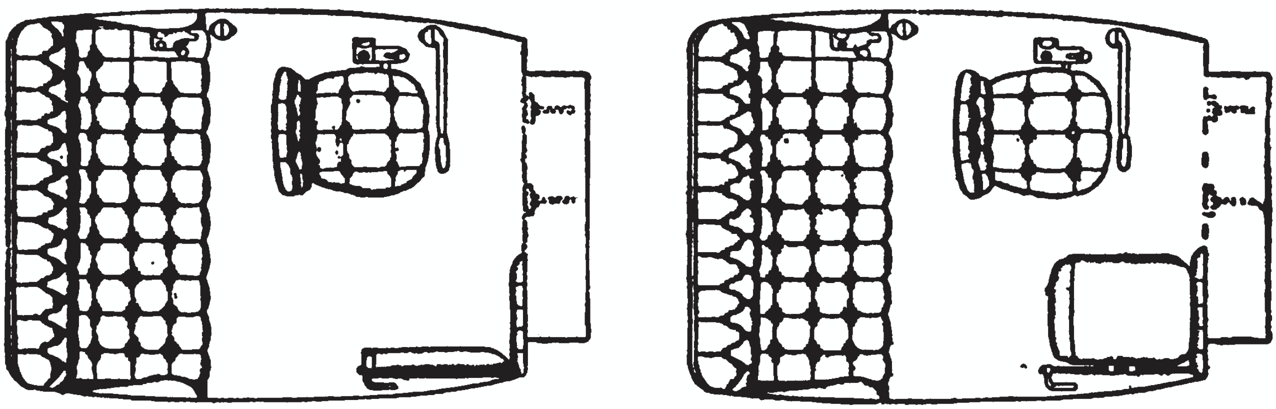


FIG. 4,062.—Side view of Baker electric chassis. The parts are: 155, front spring; 155-C, front spring bolt, front; 155-D, front spring bolt rear; 157-A, front spring shackle; 157-E, front spring shackle lock plate; 158, rear spring bracket center; 159, rear spring; 159-C, rear spring bolt; 173, step pad; 179, step bracket; 187-A, front hanger for rear spring; 188-A, rear spring shackle; 188-E, rear spring shackle lock plate; 253-X, rear control mast; 257-A, rear control mast bracket, lower; 279-X, steering mast, rear; 287-A, steering mast bracket, rear; 453-C, safety loop, short; 453-D, safety loop, long; 500-X, controller; 647-A, seat pedestal bracket, left; 647-C, seat pedestal tube, left; 647-D, seat pedestal stop cup; 688-X, opening switch; 694-X, closing switch; 753-X, front control mast; 757-A, front control mast bracket, lower; 779-X, steering mast, front; 787-A, steering mast bracket, front; 796-X, lower steering rod, mast to bell crank; 3,937, rear spring clip, 4,406, 4,411, 4,415, grease cups.

Electric Vehicle Essentials.—The three essential features which convert a vehicle into an electric automobile are the battery, the motor and the system of transmitting power from the motor to the propelling wheels.

In order to move a body from one point to another, it is necessary to apply power to overcome the various opposing forces that always exist. In putting any body, say a carriage, into motion, the effect of its weight, called inertia, opposes the force producing the motion. Inertia requires an application of



FIGS. 4,063 and 4,064.—Waverly alternative seating arrangements.

force directly proportional to the rate at which the vehicle is accelerated. Besides this, there are several forces which are active not only on starting and increasing the speed, but when a uniform motion has been attained. These forces are: 1, wind pressure; 2, internal friction of tires; 3, losses in the various moving parts; 4, electrical losses in battery; 5, electrical losses in wiring and motor; 6, gravity in ascending hills.

All these forces which are met when the vehicle is under motion absorb more or less power, and, as in an electric machine the quantity of energy that can be stored is limited, it is of the greatest importance that the designing engineer should bear in mind the vital necessity of cutting down these opposing forces as much as he possibly can.

Wind Pressure.—The resistance of the air encountered by a vehicle at normal speed is not a very serious matter, but with an increase of speed or with a head wind, the loss becomes quite large and racing cars are built with the idea in view of reducing the area exposed to the wind and so shaping the exposed parts that the machine will cut its way through with the smallest amount of retardation.

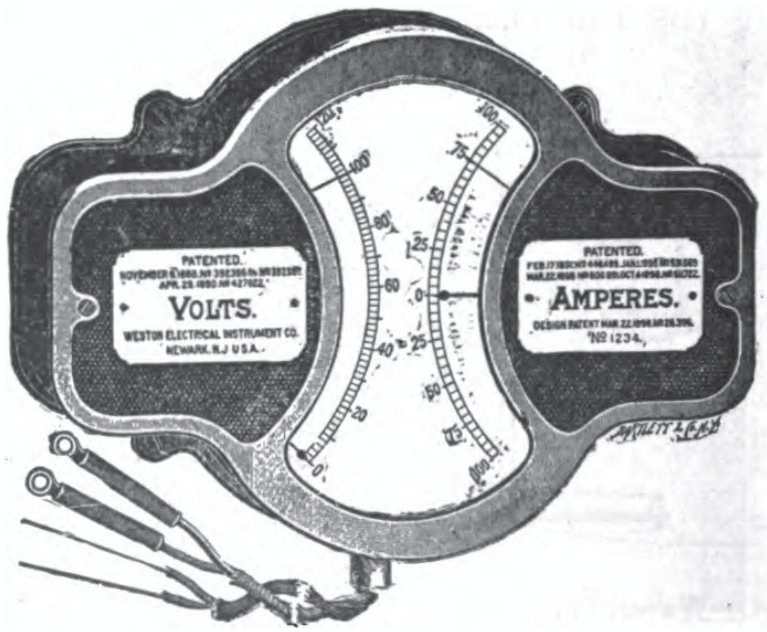


Fig. 4,065.—Weston volt ammeter of the type used on electric vehicles. In some types, the index is side by side instead of end to end.

Tire Friction.—The most important loss, perhaps, and one that is least understood is the effect of tires.

It is clear that the portion of any tire which is in contact with the earth must be flattened, but in order to do this, not only must some other parts of the outer surface of the tire assume a deformed shape by creeping, but there must be a change in the relative position of the internal particles. If the tire be a double tube, pneumatic, the inner tube will rub against the casing and the casing will have more or less play against its fastening.

In every pneumatic tire, besides the rubber composition there must be a certain amount of tough cotton fabric which gives the entire structure its strength. In most tires of standard make this material is inserted in the shape of canvas fairly closely woven and quite stiff. In these tires the elasticity of the rubber is restrained and controlled by this cloth, and it is readily seen that there is but little of the power of flattening or adapting itself to the road that would oe possible by the same tire were rubber used alone.

Thread and cord fabric tires have been developed with the intention of retaining the strength of the cotton and at the same time permit of more freedom of motion than canvas will allow. The idea is to use independent threads or cords and surround them with rubber. The one layer of such threads being wound in the direction of the thread on a right hand screw and the next layer at right angles to these. The action of all the threads will then resemble very much a strip of loosely woven cloth cut bias.

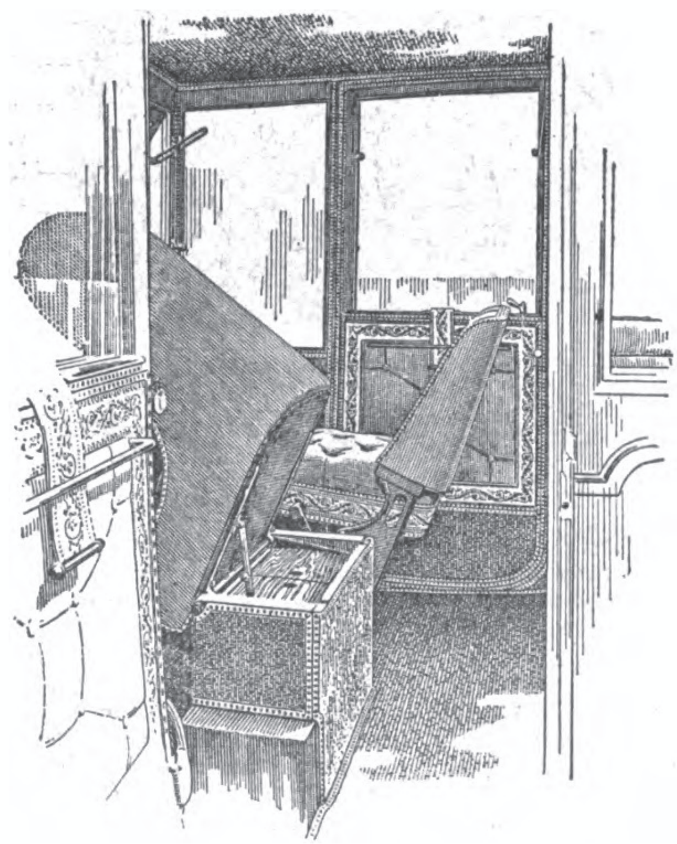


FIG. 4,066.—Interior of Borland electric. The driving seat is tilted forward to show the means of ready access to controller through the box-like base beneath the seat.

There are losses in the electric motor, controller and wiring which in importance rank next to tire losses; besides the design of the motor should be such that outside of the question of its own efficiency its propelling power should be so regulated that the maximum distance may be covered on a single charge.

In the design of electric vehicle the object of the builders should be to attain the greatest possible mileage consistent with durability; also lightness, combined with strength and efficiency in every part. To this end manganese bronze, aluminum, seamless tubing and drop-forged steel are the materials that are largely used.

Motors for Electric Vehicles.—These are of the enclosed type of construction, which of necessity they must be, in order to protect them from dust, etc., in their exposed positions under the car. They are designed for heavy overloads.

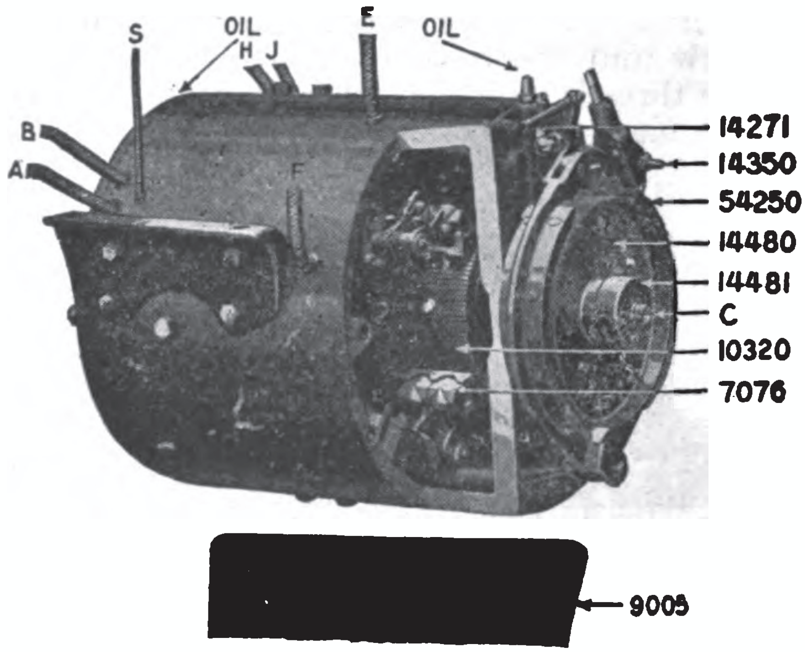


FIG. 4,067.—Rauch and Lang electric vehicle motor. ***Instructions for care of motor:*** The two oil covers lead to the ball bearings in the motor yokes. A good grade of light cylinder oil is recommended for these bearings. The commutator, 10,320, should be at all times kept clean, free from any gummy or gritty substance. The carbon brushes 7,076 should make perfect contact with the surface of the commutator and should be replaced with new ones when worn out. These brushes are originally $1\frac{5}{8}$ inches long and should be replaced with new ones as soon as the measurement is reduced to $1\frac{1}{4}$ inches. It is safer to replace these brushes often, rather than allow them to become too short. Very serious damage may result from using brushes that are too short or ones that make poor contact with the commutator. Brushes that are too short or that are making poor contact will pit, burn and blacken the surface of the commutator. Replacement of brushes should be made only by an experienced person. The motor leads are lead out of motor through insulated holes. These holes, lettered J, H, B, A, S, E and F correspond to the letter contacts on the controller into which they are connected. The motor brake may be adjusted for wear by means of the winged nut 14,350. Clearance between brake jaws and wheel may be adjusted by means of the screw 14,271. To remove brake wheel from armature shaft, take the $\frac{5}{16}$ screw C out of the cap 14,481. A $\frac{1}{2}$ inch, 12 pitch bolt, 3 inches or longer, or a cap screw may then be screwed through the threads in the cap and up against the end of the armature shaft. Continue to turn this screw and the pulley will be drawn off the shaft.

When a vehicle is started or its speed increased, a certain amount of energy is absorbed to produce this acceleration. The total amount of energy required is in proportion to the total weight and to the square of the velocity, so that to double the weight of a vehicle means doubling the power required for starting, and doubling the velocity means four times the power. Accordingly, to meet these conditions, especially when starting under severe conditions, as on a sandy road, or in ascending a hill, the electric vehicle motor is constructed for a 200% or more overload.

As stated by one manufacturer, a motor for a two passenger runabout rated at 2½ horse power consumes 6,800 watts in ascending an 11 per

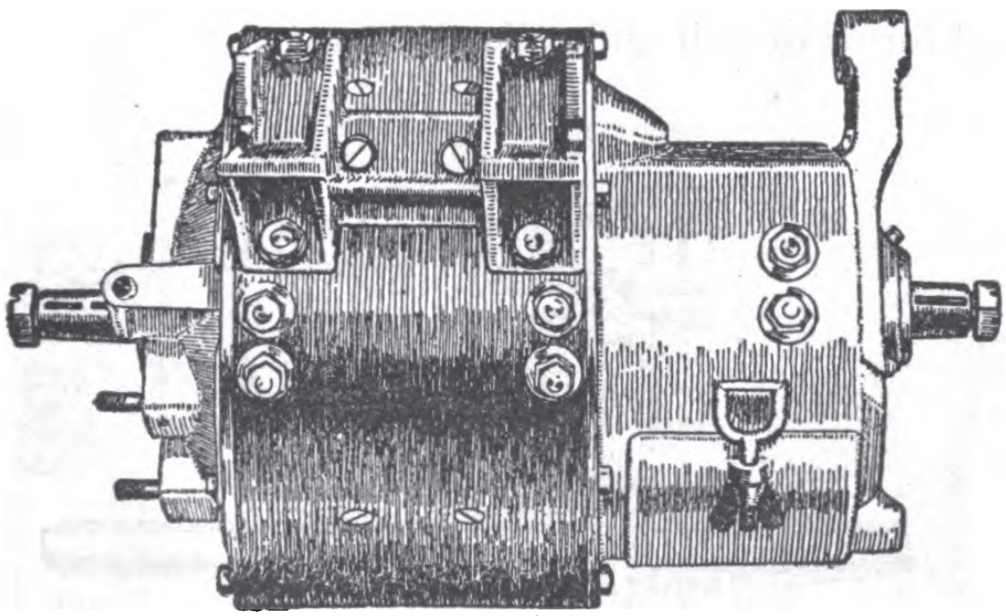


FIG. 4,068.—Waverly 80 volt motor. *In construction* it is series wound medium speed. The armature rotates on ball bearings; four poles are used.

cent. grade at 7 miles per hour, although no more than 360 watts are required to propel the vehicle 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 vehicle motors, but, as a matter of fact, they are wound to develop the highest constant power output at the highest voltage used, with a high overload capacity for short spurts, as in hill climbing, etc.

Ques. What objectionable feature should be avoided in electric vehicle design?

Ans. Very quick acceleration, because a vehicle. constructed with this feature, not only gives the passenger an unpleasant jerk, but puts a heavy overdraft on the battery.

Ques. What are the considerations with respect to friction in the bearings?

Ans. Since the amount of power lost by friction in the bearings requires that much more power to be carried by the vehicle, in order to attain the desired mileage or speed, it is very essential to reduce frictional losses to a minimum by using approved forms of ball and roller bearing.

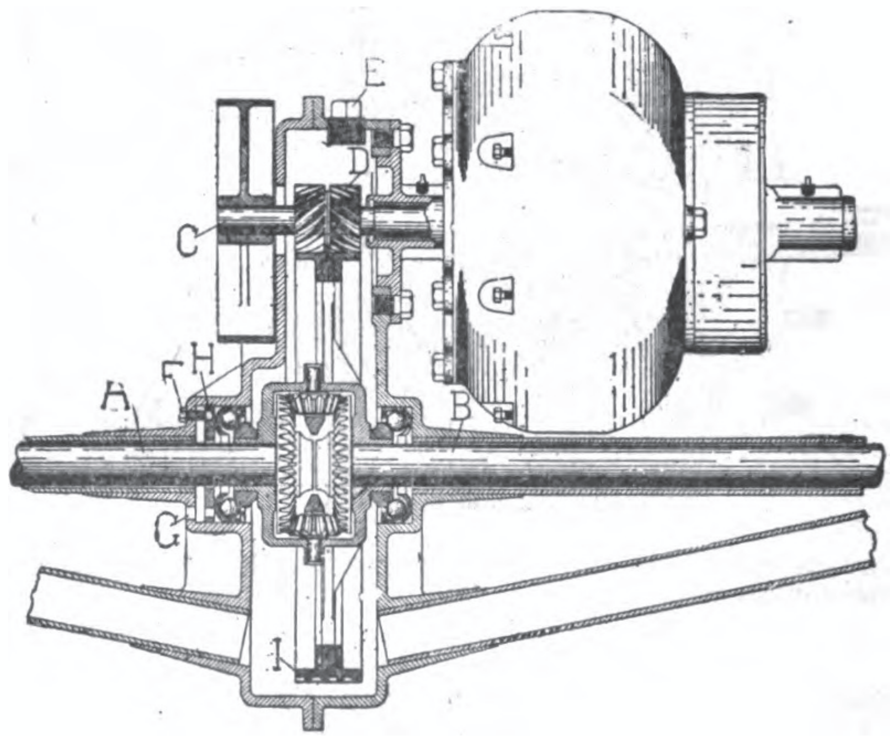


FIG. 4,069.—Diagram of a single motor attached to rear axle through "herringbone" single reducing gears. A, is the left hand section of the divided rear axle; B, the right hand section of the rear axle; C, the brake drum; D, the spiral pinion on the motor shaft driving the worm gear, I, on the differential; E, plug for greasing gears; F, set screw for locking ball race; G, slot for wrench to adjust threaded ring, H, against ball bearings.

The Drive or Transmission.—Because of the relatively high speed of the motor as compared with that of the rear wheels of the car, a system of gearing is necessary between the motor and rear axle to obtain the necessary velocity reduction. Moreover, in some cases, other gears must be provided so that the power may be applied to the rear shaft when the motor shaft and rear shaft are at right angles to each other.

There are several forms of drive, as by

1. Herringbone gear;
2. Chain gear;
3. Worm gear.

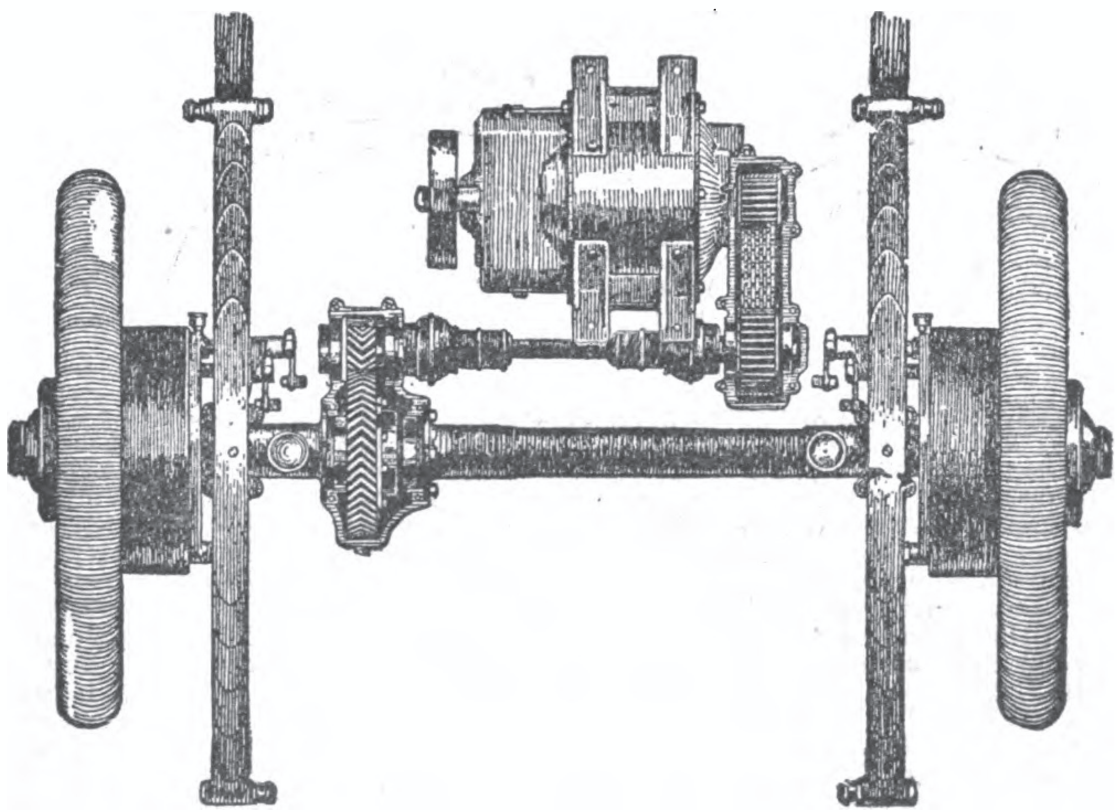


FIG. 4,070.—Waverly double reduction gear or combination herringbone gear and "silent" chain. ***In construction*** the motor shaft is parallel to the intermediate or jack shaft and drive shaft. Two universal joints are used, so as to give freedom of motion in any direction. The motor weight is above the springs. The first reduction is by the silent chain enclosed in a casing at end of motor; the second reduction is through the herringbone gear in the axle.

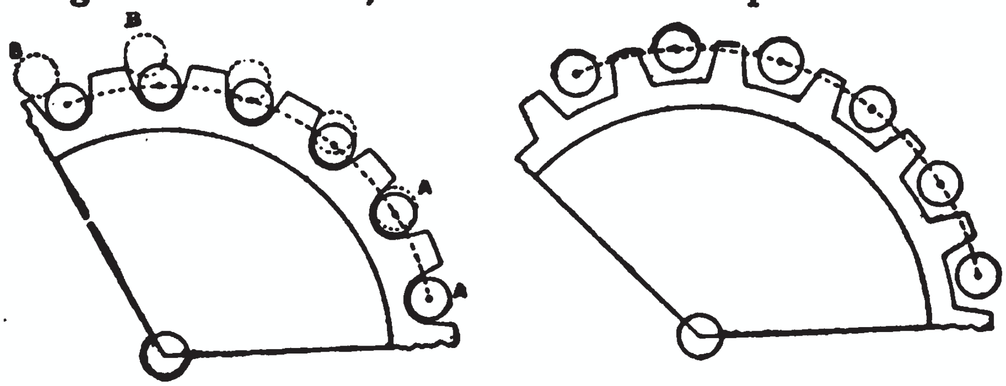
Herringbone Drive.—This type of drive gear is extensively used.

The method of attaching a single motor to the rear axle through herringbone single reducing gears is shown in fig, 4,069. A and B, are the two sections of the divided rear axle. The spiral pinion D on the motor shaft drives the worm gear I, on the differential. C represents the brake drum; E, the plug for greasing gears; F, the set screw for locking ball race; and G, the slot for wrench for adjusting threaded ring H, against the ball bearings.

The advantages of this sort of drive are its freedom from noise, its simplicity and durability owing to the parts being enclosed.

Chain Drive.—This form of drive is desirable for heavy service, as on very large trucks. It is a noisy and dirty mode of power transmission, and when not enclosed is subject to rapid wear.

In chain drives there is more or less elongation of the chain due to the wear of the rivets and bearings or to stretch of the material. To guard against the latter, chain makers use special material of high



Figs. 4,071 and 4,072.—Diagrams showing the behavior of a chain on a sprocket of equal pitch, and on one of properly unequal pitch. The following quotation from an English authority explains the action: "A chain can never be in true pitch with its sprocket. A pair of spur gears tend, to a certain extent, to wear into a good running fit with each other, but a chain, if made to fit its sprocket when new, does not continue do to so a moment after being made, as wear at once throws it out. This being so, it must be put up with, and involves the consequence that a chain can only drive with one tooth at a time, supplemented by any frictional 'bite' the other links may have on the base of the tooth interspaces. If the chain be made to fit these accurately (taking a roller chain for illustration), it is obvious that the least stretch will cause the rollers AA to begin to ride on the teeth as at BB. If, however, the teeth be made narrow compared with the spaces between the rollers, a considerable stretch may occur without this taking place. The roller interspaces, then, should be long, to permit the teeth to have some play in them, while retaining sufficient strength, as shown in fig. 4,072. In order that the driving sprocket may receive each incoming link of the chain without its having to slide up the tooth face, it should be of a somewhat longer pitch than its chain, the result being that the bottom tooth takes the drive, this being permitted by the tooth play shown in fig. 4,072. This difference, of course, gradually disappears as the chain stretches. The back wheel sprocket, on the other hand, should take the drive with its topmost tooth, and hence should be of slightly less pitch than the chain, but as the pitch of the latter constantly increases, it may be originally of the same pitch. The only remaining point with regard to design, and one which the owner of a car may easily ensure, is that the number of teeth in the sprockets should be prime to that of the links in the chain."

tensile strength, but if, for any reason, a link elongates unduly, it should be replaced at once, as one long link will eventually ruin a chain. Such elongation sometimes results from a sudden application of the load.

To prevent undue interference between the chain and sprocket as the result of elongation, the sprockets are not cut to fit the chain accurately but with a certain amount of pitch line clearance.

Ques. State a very objectionable feature of chain drives?

Ans. The chain sometimes climbs the sprocket teeth.

Ques. What is the cause of this?

Ans. Considerable wear or too little clearance.

If a sprocket were cut without clearance, an elongated chain would climb the teeth and the latter would exert a wedging effect, thus subjecting the chain to excessive strains. **In design** the amount of clearance should be as large as is consistent with the proper strength of the teeth.

Ques. Under what conditions should a chain operate?

Ans. It should work in oil, in a dust tight case.

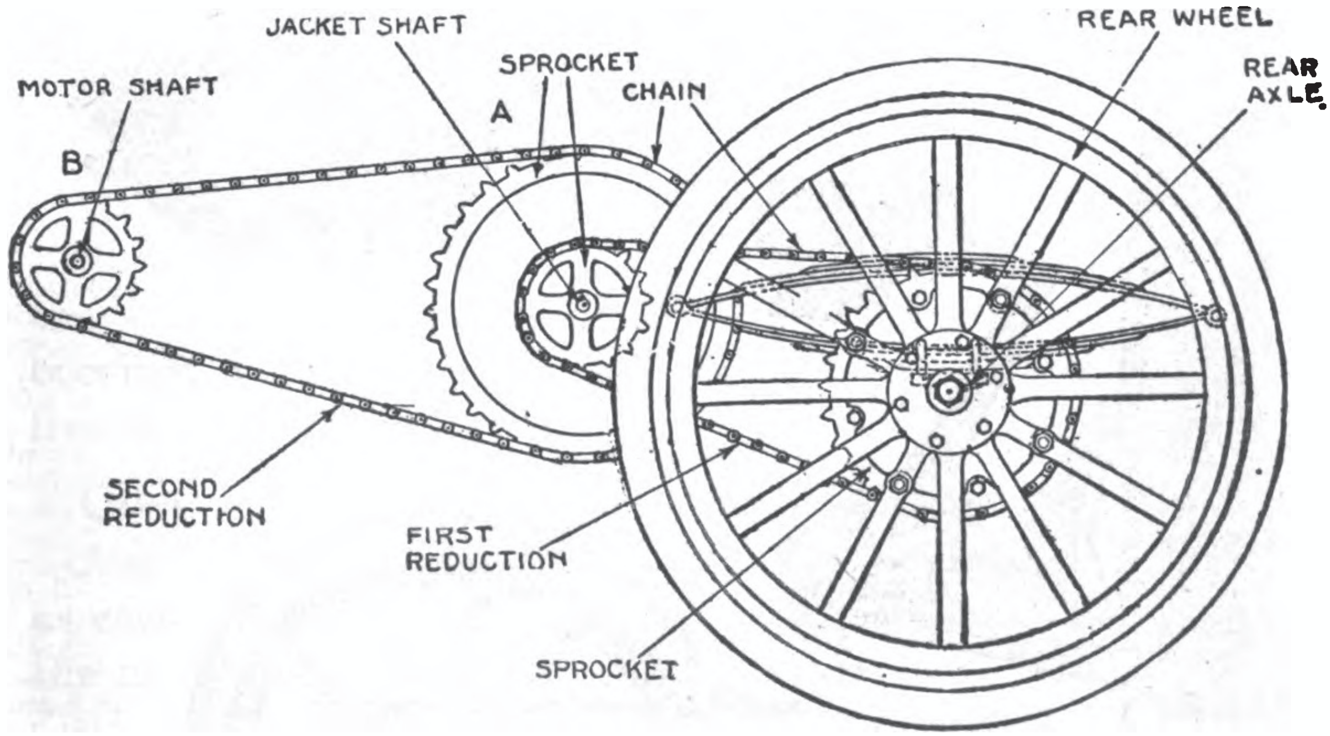


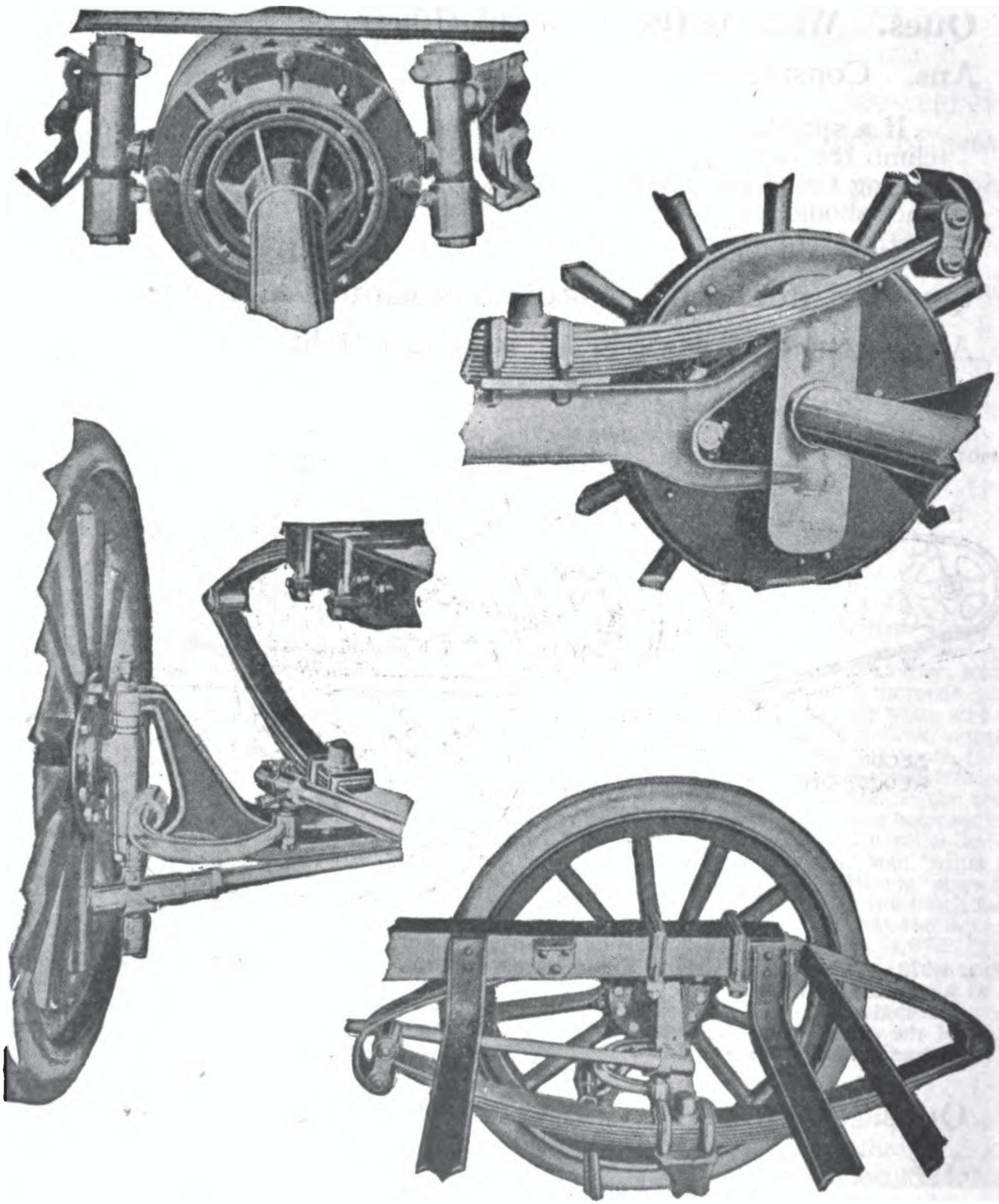
Fig. 4,073.—Double chain drive. The rear axle is of the "dead" type and each rear wheel has a sprocket with which the chains mesh. The jack shaft is parallel to the rear axle and upon the maintenance of parallelism between the two axles depends the satisfactory working of the chain. The cut illustrates single and double reduction chain drive. For single reduction the motor would be located at A, and for double reduction, at B.

Ques. What is the advantage of the chain drive?

Ans. The greater portion of the weight of the drive mechanism is supported by the frame instead of the rear axle housing; it is thus cushioned from shocks due to uneven road.

Ques. What two kinds of chain are used?

Ans. Block chain and roller chain.



FIGS. 4,074 to 4,077.—Details of Wood's electric vehicle construction. Fig. 4,074, ***motor suspension*** showing detail of the hangers between which the motor is suspended; fig. 4,075, ***radius rod connection,*** showing phantom view of radius rod and how attached to rear axle housing. Also mounting of rear spring or radius rod forward to rear axle; fig. 4,076, ***steering knuckle,*** showing connections and half of front spring; fig. 4,077, ***front spring*** showing full elliptic design and method of attaching springs to main chassis frame.

Ques. Describe a block chain.

Ans. A block chain is made of a series of block, properly shaped to fit the teeth of the sprocket, each joined to similar blocks before and after by side links bolted through the body of the block.

Ques. Describe a roller chain.

Ans. A roller chain is composed of a series of roller, known as center blocks, joined by side links. Each roller rotates on a hollow core which is turned to smaller diameter at either end, to fit a perforated side piece joining the rollers into pairs. The side links are set over these side pieces and bolted in place through the cores.

Ques. How do the two types compare in operation?

Ans. A block chain with generous slack is liable to meet the sprocket with a continual clapping, which at high speed, becomes a continuous rattle. A roller chain is comparatively free from the trouble.

Ques. What causes the snap and rattle of a chain?

Ans. The fact that even with the best designed sprocket, as each tooth in turn passes out of engagement with the chain, the next roller must be drawn forward through an appreciable distance before engaging a tooth. This action not only produces the noise, but it is a factor in waste of driving power.

Ques. What attention should chains receive to maintain a proper working condition?

Ans. The principal points to be observed in the use and care of sprocket driving chains are: 1, to maintain the proper tension in order to avoid "whipping"—which, particularly with a long one, is liable to result in snapping of the chain,—and, at best, involves a loss of driving efficiency. The chain should not be drawn too tight. lest a similar disaster result. Some slack must always be allowed, 2, two sprockets should always be kept in alignment. In the case of a double chain drive, from a counter shaft parallel to the rear axle, care should be exercised to maintain the parallelism, even preferring a somewhat loose chain to a tight one that strains the countershaft, 3, if a link show signs of elongation, it should be replaced by a new one, 4, whenever the chain is removed for cleaning or other purpose, it must be carefully replaced, so as to **run in the same direction**

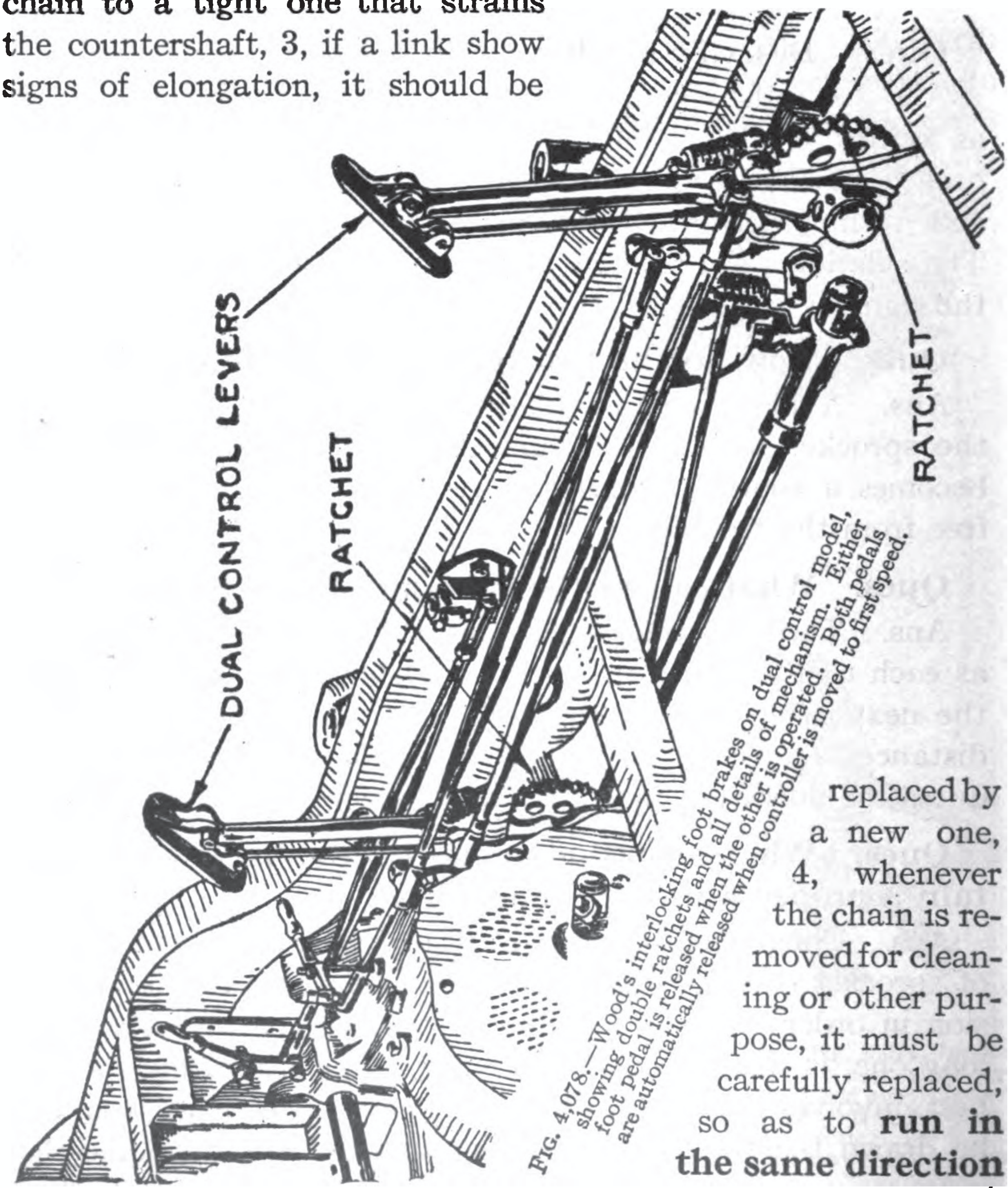


FIG. 4,078.—Wood's interlocking foot brakes on dual control model, showing double ratchets and all details of mechanism. Either foot pedal is released when the other is operated. Both pedals are automatically released when controller is moved to first speed.

as formerly, and **with the same side up.** The chain should never be turned around, or its direction between the sprockets reversed, 5, a new chain should not be put on a much worn sprocket, 6, a chain should be frequently cleaned and rubbed with graphite, because the chief difficulty involved in the use of driving chains is the liability to clog and grind with sand, dust, and other abradants, and 7, after steady use for a more or less extended period, the chain should be removed and cleaned throughout.

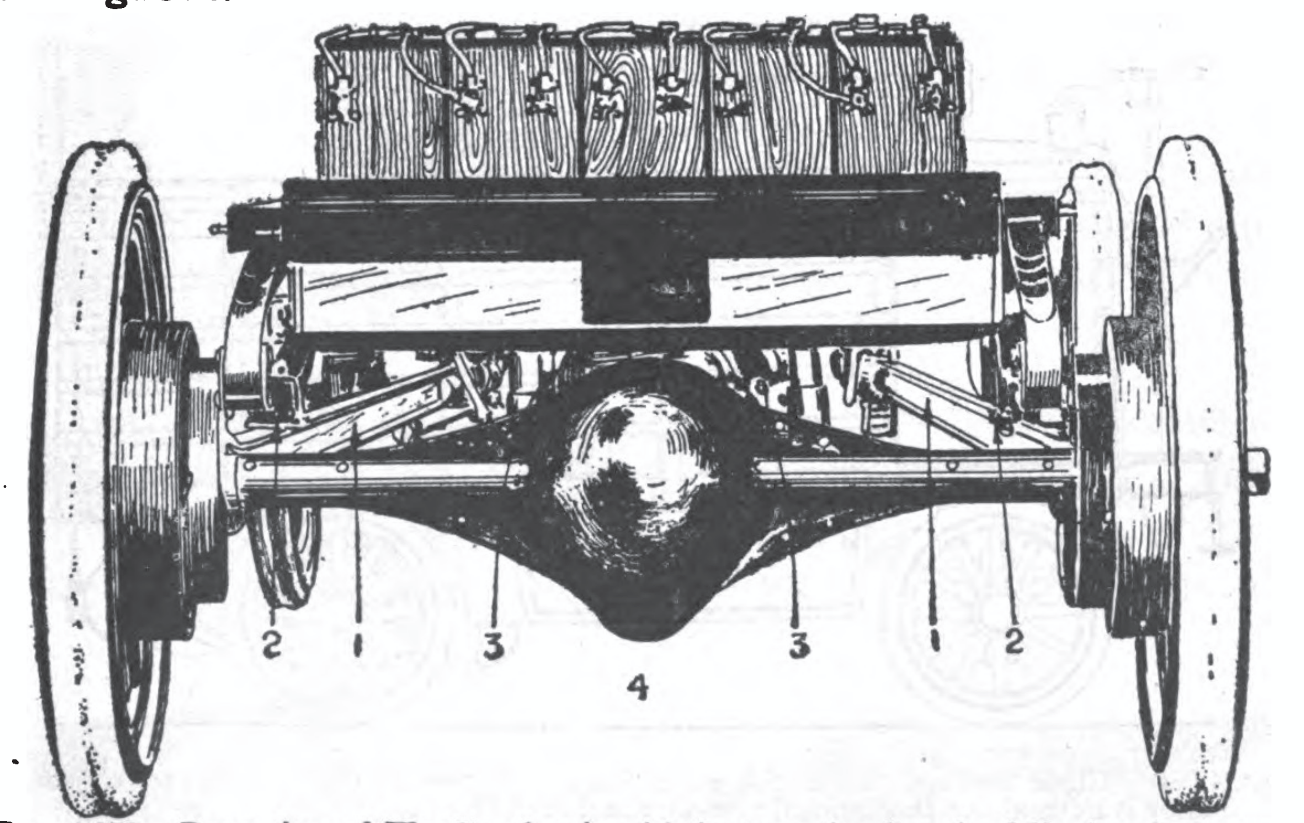


Fig. 4,079.—Rear view of Wood's chassis with battery showing the following ***features of construction:*** 1, radius rods extending from rear axle to sub-chassis frame; 2, rear springs rest on radius rods, instead of on rear axle; 3, motor, showing ball and socket spring suspension; 4, worm drive, showing location of worm below rear axle.

Ques. How may a chain be best cleaned?

Ans. After removing it from the sprockets, cleanse first in boiling water, then in gasoline, in order to remove all grease and dirt. The common practice is next to boil the chain for about half an hour in mutton tallow, which is thereby permitted to penetrate all the chinks between rolling surfaces forming an excellent inside lubricant. After boiling, the chain is hung up until thoroughly cool, at which time the tallow is hardened. It may then be wiped off clean and treated with a preparation of graphite, or a graphite alcohol solution on its inner surface.

Some authorities recommend that the chain, after it is cleaned in boiling water and gasoline, should be soaked, first, in melted paraffin for an hour at least, and then in a mixture of melted mutton tallow and graphite. After each soaking, it is dried and wiped clean. With either process, a daily application of graphite is desirable.

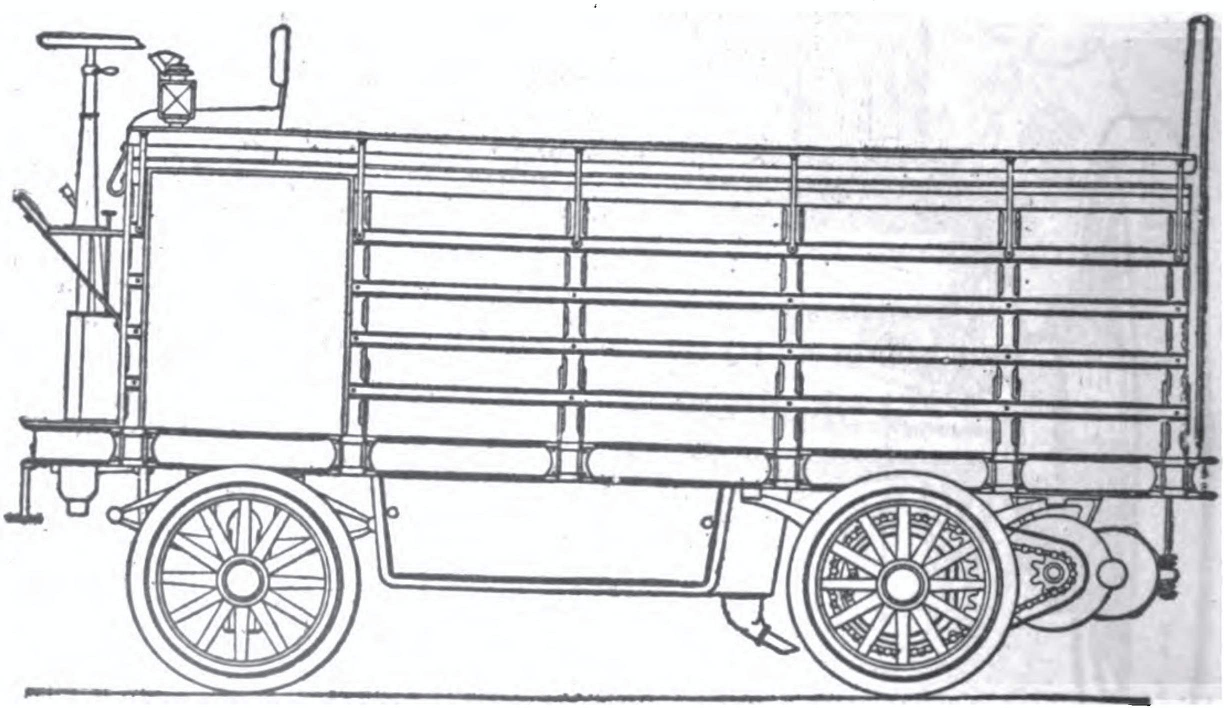


FIG. 4,080.—Chain and sprocket double reduction gear for heavy trucks. As here shown, the motor is hung above the springs, missing the jars of travel.

Ques. Is it necessary that both chains be of equal tightness?

Ans. No; the differential gear on the jack shaft will counteract this and cause each chain to do its share of the driving.

Ques. What adjustment is important with a chain drive?

Ans. The jack shaft and rear axle should be made parallel by adjusting the radius rods to secure the proper engagement of the chain with the sprockets.

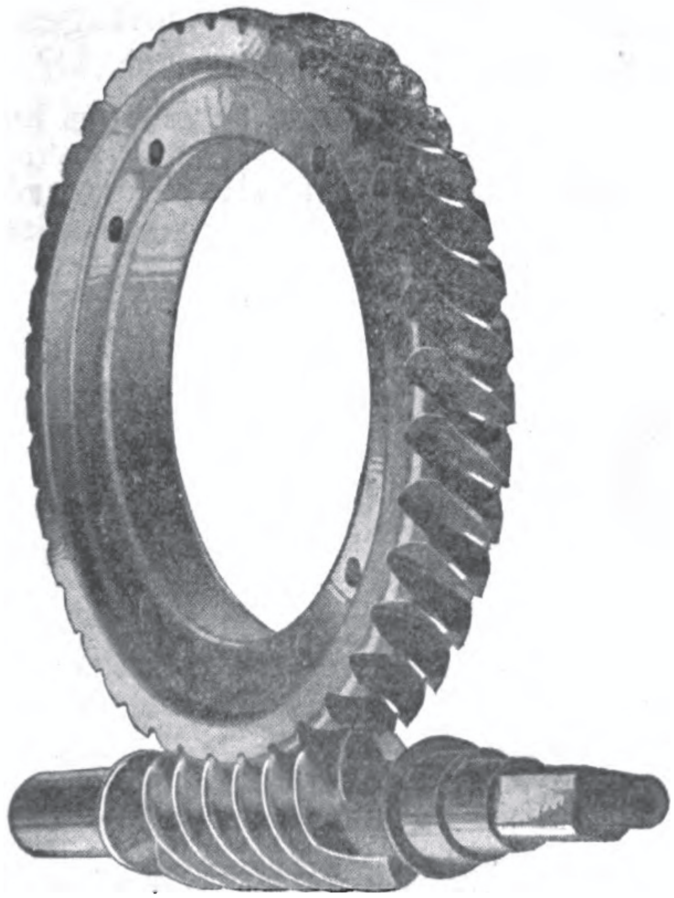


Fig. 4,081.—Baker R and L worm and gear.

Combination Chain and Gear Drive.—For very heavy trucks where a considerable reduction in speed is required between the motor and wheels, a double reduction is sometimes used as shown in fig. 4,080.

The motor is usually hung above the springs, thus being protected from the jars of travel.

There are several forms of double reduction using light high speed motors by means of various combinations of gear and chain, with silent, roller chains or herringbone gears for the first reduction, and single or double roller chains, bevel gears or herringbone gears for the second reduction.

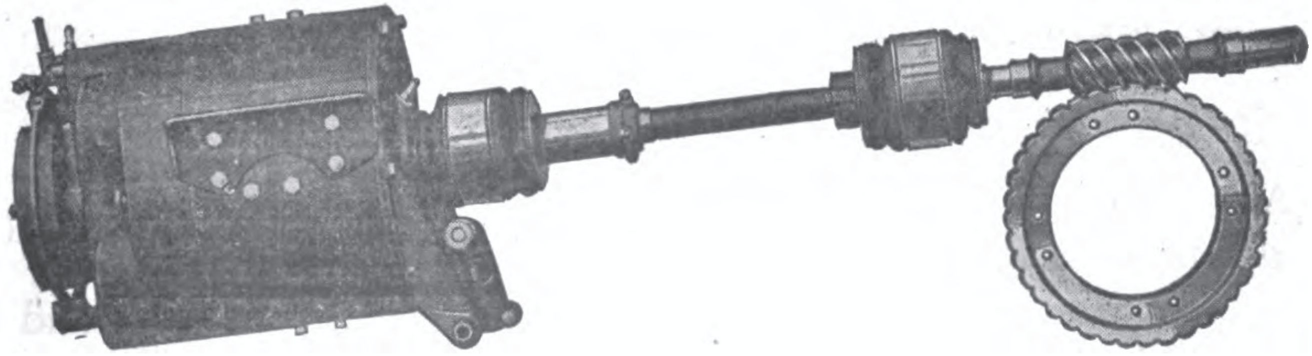


Fig. 4,082.—Baker R and L motor, propeller shaft, universal joints, worm and gear. This is the straight type top mounted worm drive.

Worm Drive.—This is a very popular drive for trucks and pleasure cars propelled by electric motors, because of the very large reduction possible on single gear. It has the advantages of silence in operation and great durability.

Ques. Describe a typical modern worm drive rear axle construction.

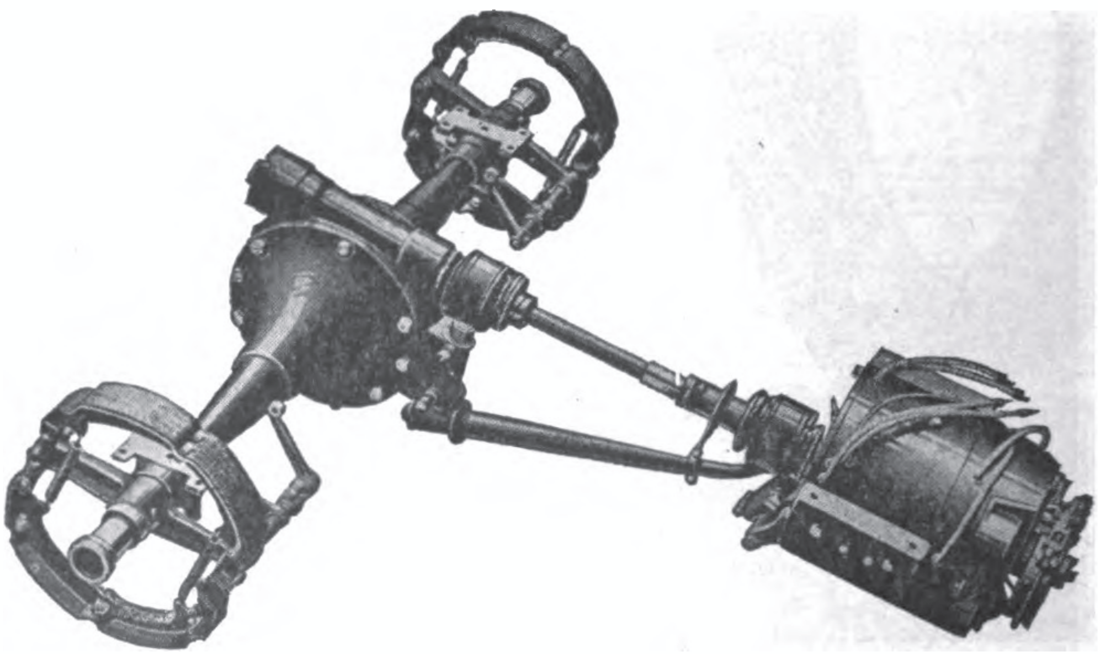


FIG. 4,083.—Baker R and L worm drive transmission unit.

Ans. The worm wheel and differential gearing are assembled as a unit with the cover of the axle housing. This housing carries all of the weight, the driving shafts being full floating and transmitting only the driving power to the wheels. A torque rod takes all driving and braking tortional strain, while two side radius rods relieve the rear springs of all tractive effort. Annular ball bearings are used to take the radial and thrust loads of the worm and wheel, while the road wheels run on conical roller bearings.

Storage Batteries for Electric Vehicles.—The storage battery has been modified in various ways to adapt it to automobile use, the problem being to secure the greatest specific energy with the least bulk and weight. Its efficiency, or the amount of electrical energy it will discharge in proportion to the amount it takes to charge it is also an important consideration. Average figures run between 70 and 90 per cent.

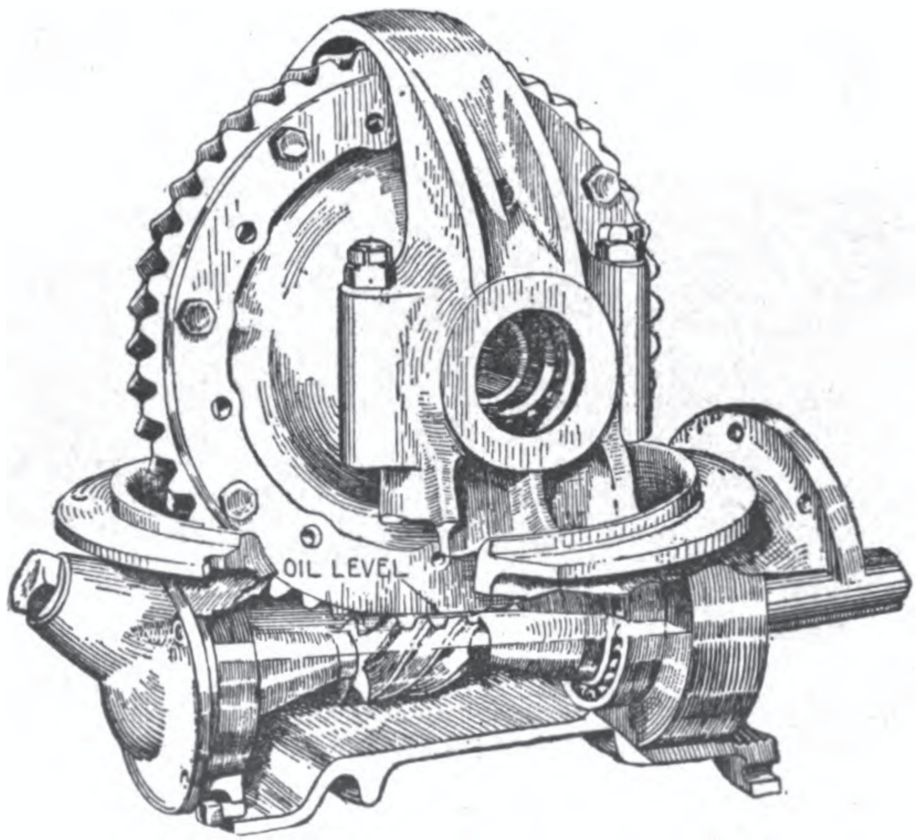


FIG. 4,084.—Lanchester type of worm drive as used on some electrics. An advantage claimed for this form of worm drive is the fact that mounting the worm below the ring gear permits it to be placed in a bath of oil, assuring constant and ample lubrication.

The storage batteries which have proved most successful in connection with electric vehicles are the lead sulphuric acid type, and the iron nickel battery, commonly known as the Edison battery.

Ques. What construction is employed to reduce the weight of battery for use in electric vehicles?

Ans. The plate surface is finely divided.

The following methods are those most common: scoring, grooving, laminating, casting, pressing and by the use of a lead wool.

The Faure, or pasted type plates are usually lighter and of higher capacity than the Plante, but have a tendency to shed the material for tne grid thus making the battery useless.

Mileage and Battery.—If the proper mileage per charge be not obtained when all mechanical parts of the car are in good order, it is undoubtedly due to the battery being undercharged and not brought up to full voltage as indicated on the meter.

In this case it is best to discharge the battery until voltage indicates 1.8 per cell; open the hoods over the battery, remove plugs from cells

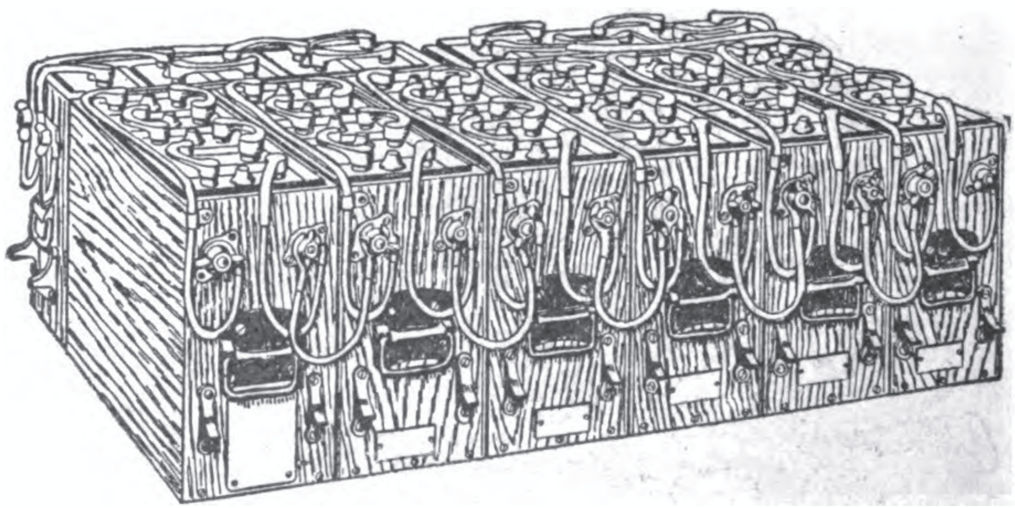


FIG. 4,085.—Waverly 42 cell lead battery. All battery cells are accessible from outside of car by raising the hoods. The battery compartments are lined with acid proof material to prevent acid reaching the paint, the running gear or other parts.

and cover the plates with *distilled* water to within one-half inch of the inside top cover. Charge the battery in the usual way until it reaches a maximum voltage as given on charging card, then charge four hours longer at the lowest rate shown on the card. Try battery; if this do not improve the mileage sufficiently, repeat the operation as before. If after repeating the operation three times, normal mileage be not obtained, and trouble be not found elsewhere the maker of the battery should be consulted at once.

* **Points Relating to Storage Batteries.**—The following important directions should be carefully followed to obtain satisfactory service for a storage battery:

* NOTE.—For a full treatment of the subject of storage batteries, see Guide No. 4.

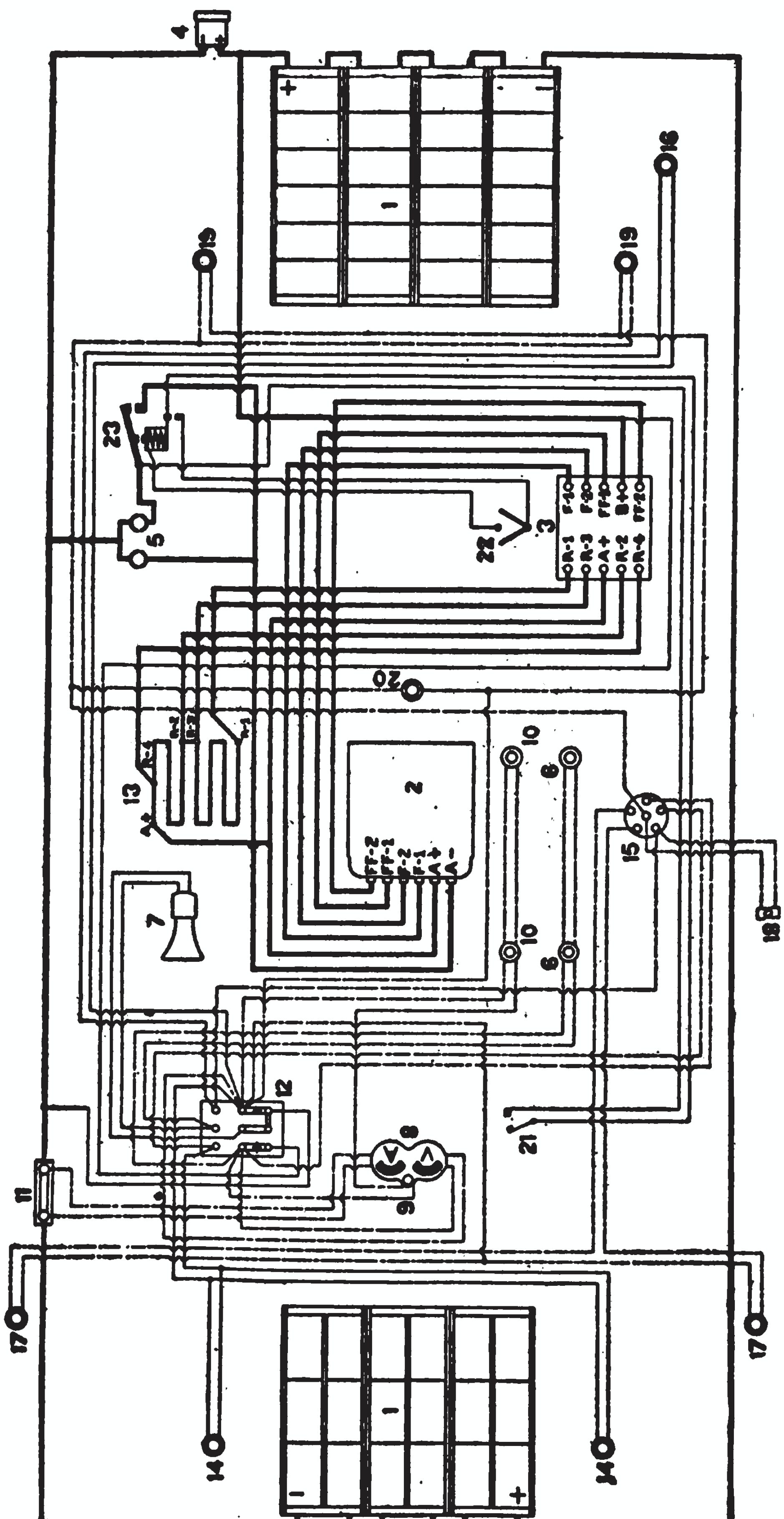


FIG. 4,086.—Wiring diagram of Baker electric. 1, batteries; 2, motor; 3, controller; 4, charging receptacle; 5, starting plug receptacle; 6, signal button; 7, horn; 8, volt ammeter; 9, meter light; 10, meter light button; 11, shunt for volt ammeter; 12, fuse box; 13, resistance guides; 14, head light wires; 15, light switch; 16, tail light wires; 17, side light wires; 18, door jamb switch; 19, inside rear corner lights; 20, dome light; 21, opening switch; 22, closing switch; 23, contactor.

1. Keep the battery and connections clean.

2. Go over the same and see that they are bolted up tight.

3. If there be any low cells in the battery, attend to them at once.

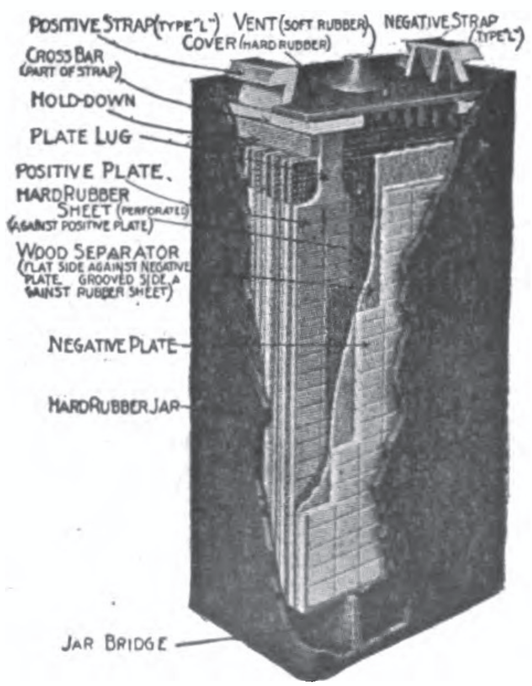
4. Keep the electrolyte, or battery solution, at the proper height above the tops of the plates.

5. Keep the density of the electrolyte, or battery solution, at the proper point.

6. Do not charge at a rate that will make the cells exceed 100 degrees F. in temperature.

7. A battery can be ruined in three hours after it has been put in use by being left on charge at a high rate after it is full.

8. The user of the vehicle should keep careful track of the charging and, if possible, watch it personally.
9. In all cases follow strictly the instructions furnished by the maker.
10. Do not let battery stand completely discharged.
11. Do not let battery fully discharge in cold weather.
12. Do not let battery stand in a partly discharged condition long.
13. Do not go away on a visit and allow battery to stand inactive.
14. A battery must be worked constantly to get satisfactory service and when going away for two weeks or more, it is best to make arrangements to have the battery looked after by someone familiar with it.
15. In charging, always connect the positive wire of the charging source to the positive terminal of the battery and vice versa.
16. If the battery become dead, or lose mileage, consult the makers.
17. Charge battery in a warm room in winter.
18. In consulting the makers, be sure to give full particulars.



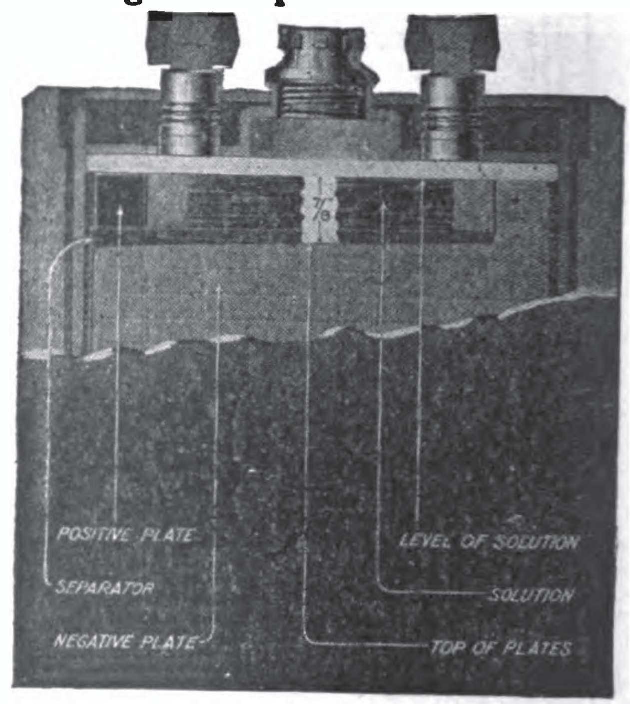


FIG. 4,079.—Gould cell showing parts.
FIG. 4,088.—Sectional view showing height to fill Gould starting and lighting type of cell.

Battery Capacity.—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.

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 be 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 be 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; batteries give only the 3 and 4 hour discharge rates in specifying the capacity of their products.

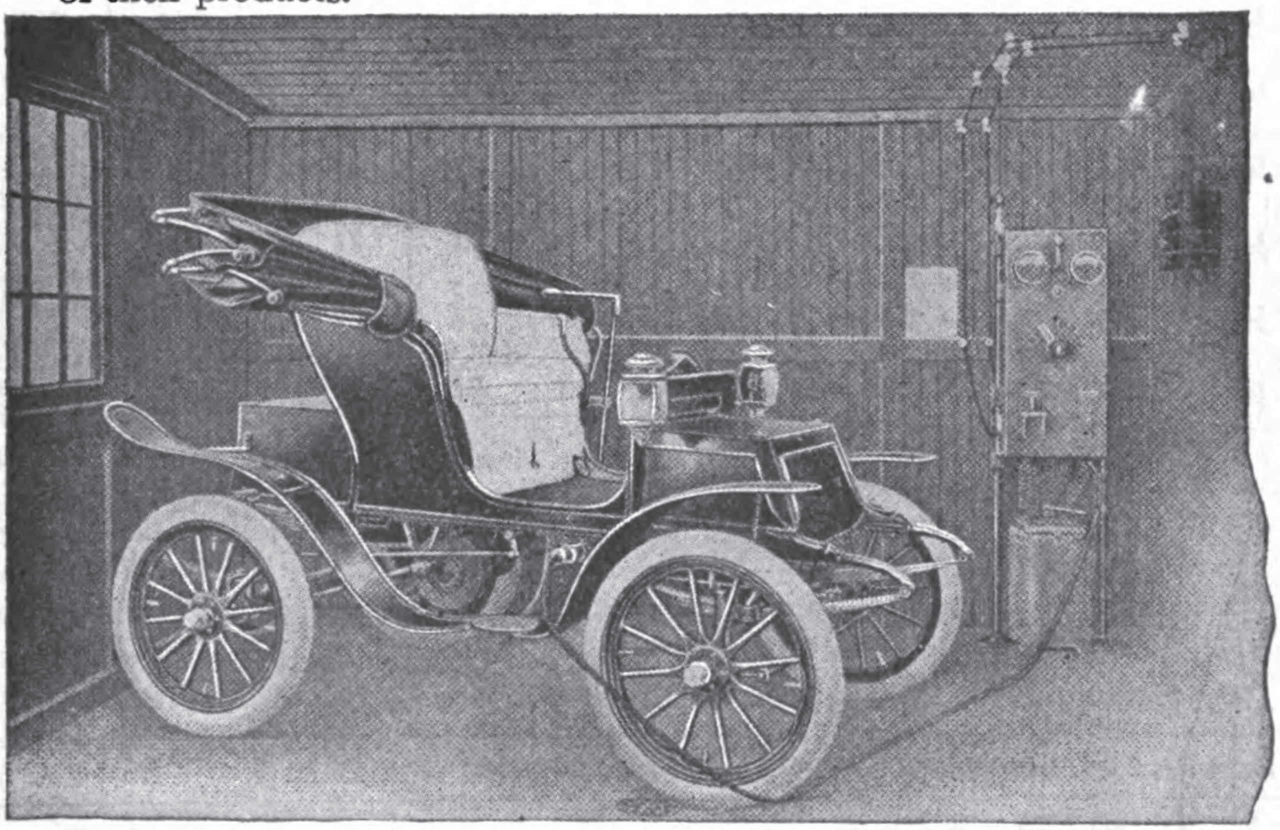


FIG. 4,089.—View showing Studebaker electric in home garage connected to rectifier charging outfit. The subject of rectifiers has been treated at such length in Guide No. 6, that no further explanation is here necessary.

NOTE.—*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 rule, such a procedure should not be adopted unless the battery be thoroughly discharged. In charging a battery at a high rate, the danger to be avoided is the tendency of the cells to heat. 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 shown in the table of high charging rates, 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.

The following data on sizes suitable for automobile use will be found useful.

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	4¾
8¾	12¼	17½	70	61¼	52½	8¾	12½	7⅞	4¾
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	8⅝
52½	73½	105	420	367½	315	52½	12½	11⅛	8

NOTE.—The figures will vary for different rates largely due to the number of plate per jar and to other points of construction.

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

NOTE.—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.* Generally speaking, the voltage during discharge is an indication of the quantity of electricity remaining within the cell.

Electric Vehicle Controllers.—The form of controller adapted to electric vehicle use consists of a rotatable insulated cylinder carrying on its circumference a number of contact, arranged to make the desired connections with the terminals of the various apparatus in the circuit through a wide range of variation.

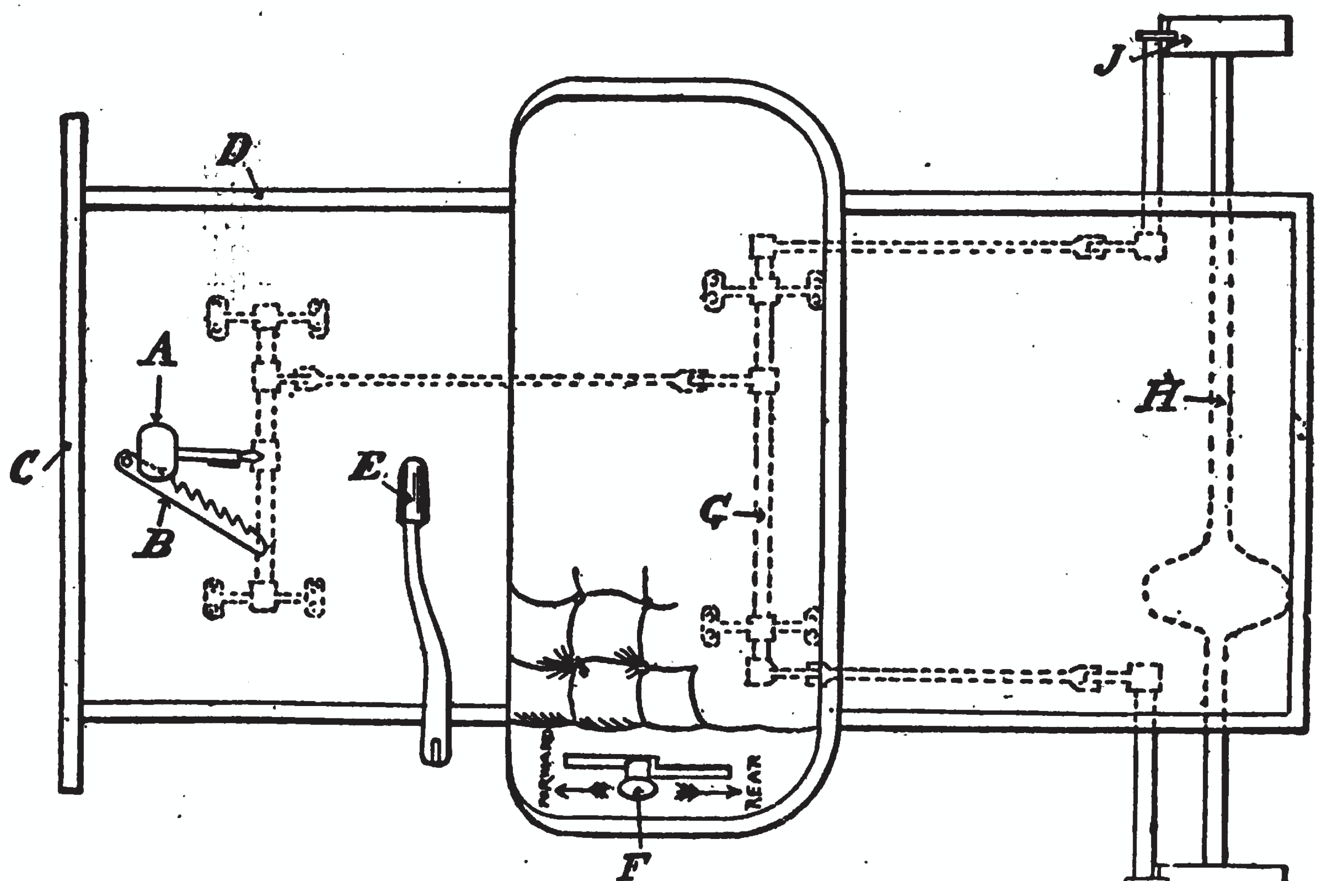
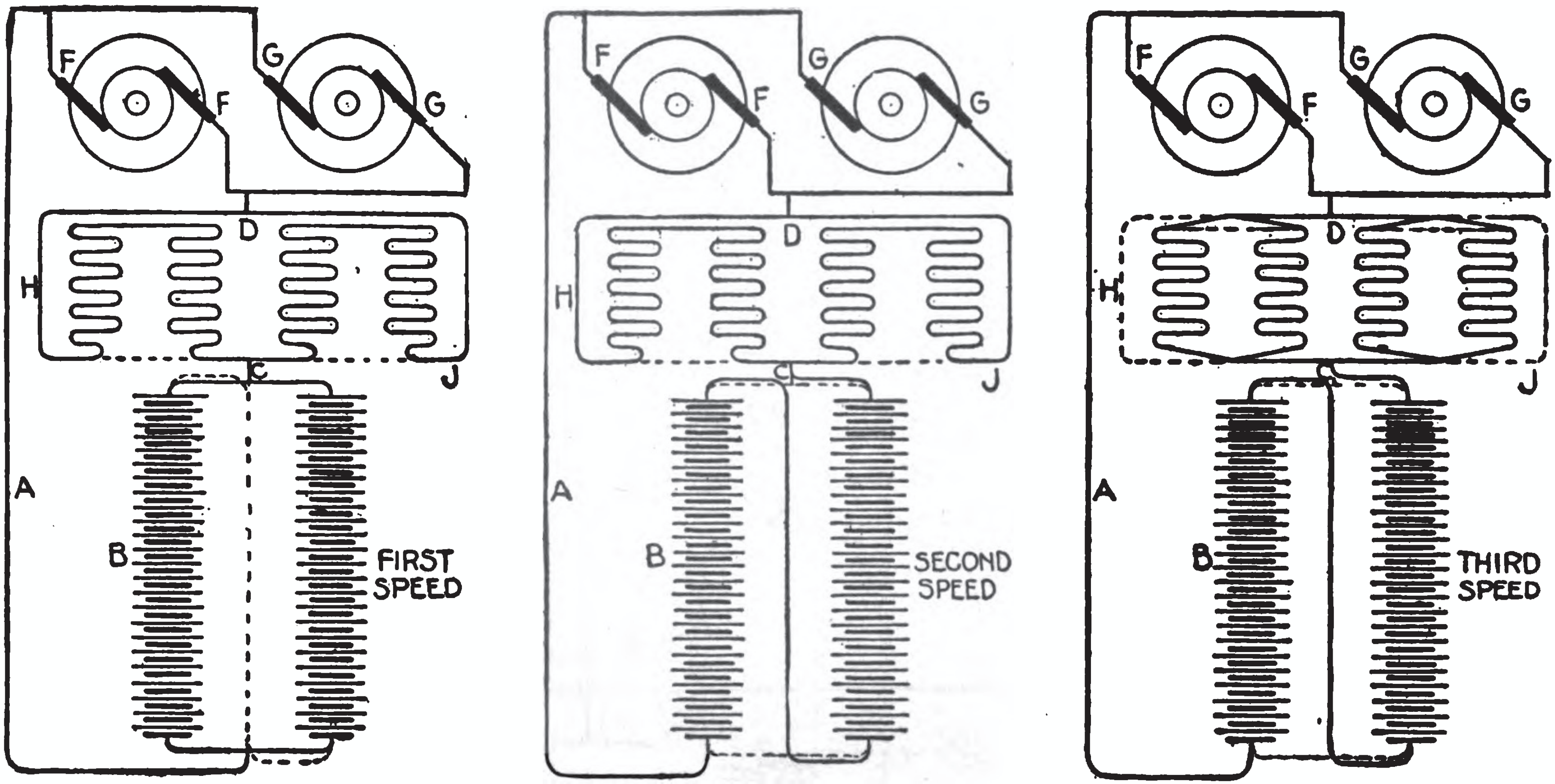


FIG. 4,090.—Diagram of the controlling apparatus of a light electric vehicle. A, brake pedal; B, ratchet retaining pedal in place, operated by left foot; C, dash board; D, body sill; E, steering handle; F, controller handle; G, rocker shaft for setting hub brakes; J, brake band on wheel hub; H, rear axle.

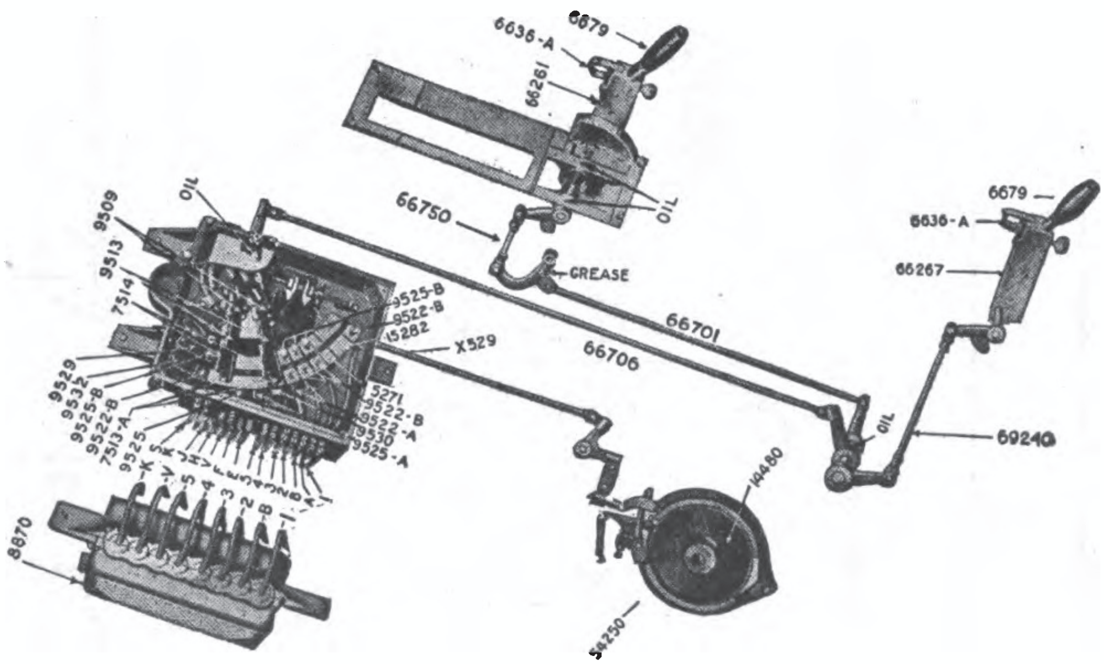
Some controllers are constructed with a cylindrical surface, upon which bear single leaf springs, the desired electrical connections being made by suitably connected conducting surfaces on the cylinder circumference, and cut outs being similarly



FIGS. 4,091 to 4,093.—Diagrams of the **circuit changing** arrangements of a typical **electrical vehicle. The full lines** in these diagrams indicate the closed or active circuits; the dotted lines the open, or inactive circuits. As may be readily understood, the whole seheme of the 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, FF and GG, and the field windings H and J, and the wire D. Fig. 4,091 shows first speed; two units of the battery B are connected in parallel, 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-parallel, 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 parallel, the return path to the negative pole of the battery being through the wire A. In fig. 4,092, the circuit is varied so as to connect the two units, 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 fig. 4,093, 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 voltage generated by their operation is equivalent to the voltage of only one motor, with the result that the speed and power efficiency is raised to its highest point.

accomplished by insulating surfaces, bearing against the spring contacts at the desired points. This type of controller is one of the most usual forms for motor vehicle purposes.

As is 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. This is done in a number of controller, the reverse being accomplished at a definite notch on the quadrant of the shifting lever.



Figs. 4,094 and 4,095.—Baker R and L selective dual controller, control handles, resistance and motor brake. ***General care:*** keep the plates 9,522-B and 9,525-B on the face of the controller and the shoes 7,513-A on the movable arm clean and free from burned and rough edges. The contact plates 9,522-B and 9,525-B and the shoes 7,513-A are the ones that become damaged first. They are removable and when badly worn may be replaced with new ones. ***Instructions for adjustment of motor brake and controller to controller handle.*** Set the controller arm fingers 9,513 in neutral position, as shown in cut, remove key from controller handle 66,267 and pull handle back to brake position and then push it forward to the stop, which is its neutral position. Have the driver's seat locked in forward running position and then the connecting rod 66,706 may be adjusted to such a length that the handle 66,267 and the controller arm fingers 9,513 will be in their respective neutral positions at the same time. After the above adjustments have been correctly made, the forward driver's seat should be turned to the position it will assume when car is to be operated from the rear seat and the length of the connection rod 66,750 adjusted to such a length that both controller arm fingers 9,513 and the rear controller handle 66,261 will be in their respective neutral positions at the same time. When these adjustments are correctly made the front driver's seat will turn freely from forward driving position to rear driving position at the time that both controller handles 66,267 and 66,261 are in their neutral positions. Adjust motor brake shoes for wear by means of the winged nut 14,350. Clearance of shoe is obtained by the adjusting screw 14,271. These adjustments should be such that the brake is perfectly free when controller arm fingers 9,513 are in their neutral position, as shown in cut. When brake is applied the top finger 9,513 will have traveled upward across the contact plate, 9,525-B, and just to the plate 9,529. The wires leading from the controlling resistance 18,870 are marked to correspond to the connectors on the side of the controller into which they are connected.

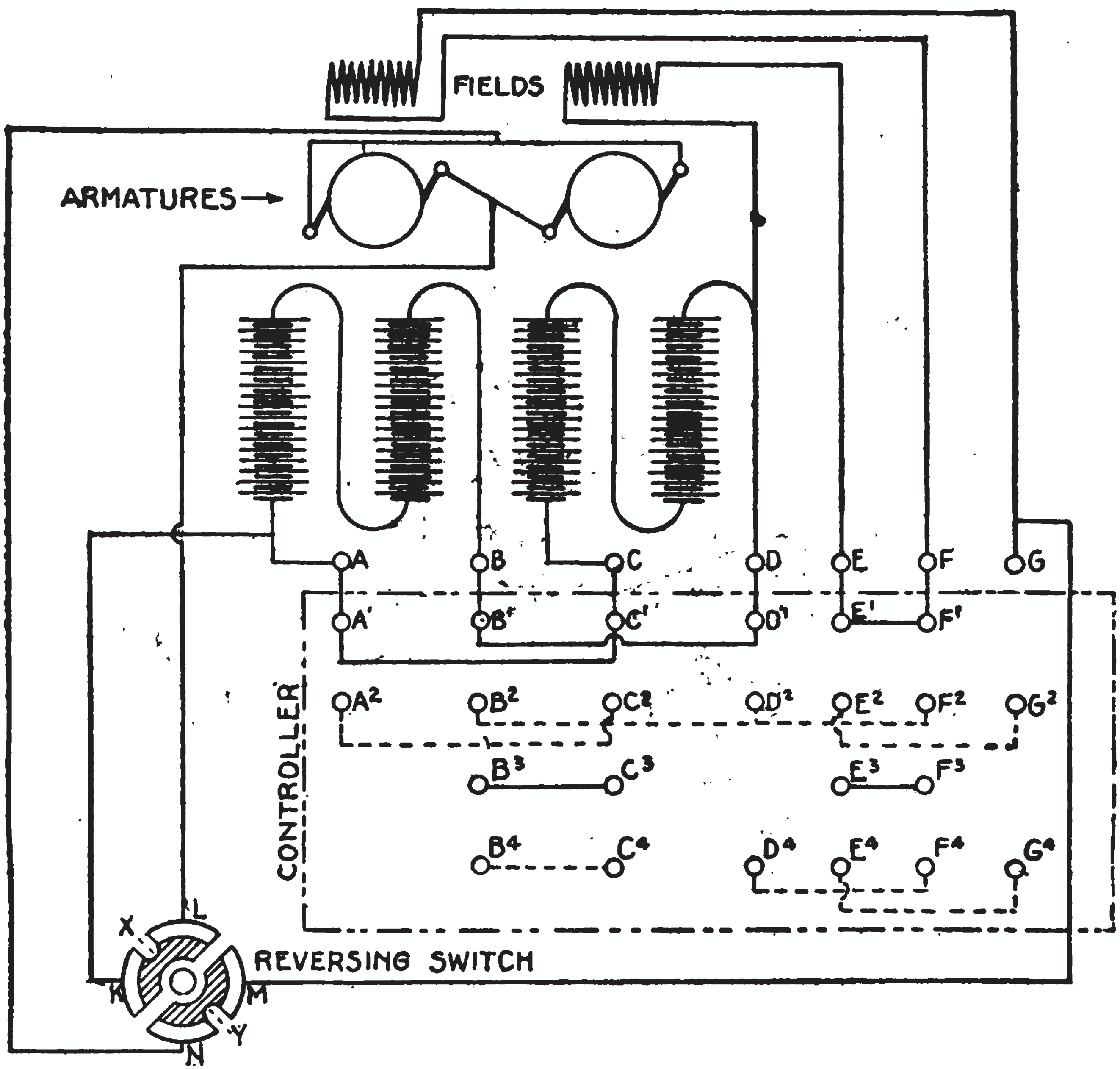


Fig. 4,096.—Diagram plan of the several parts of an electric vehicle driving circuit. The field windings and armatures are shown projected, the proper wiring connections being indicated. The periphery of the controller is laid out within the broken line rectangle, the contacts and connections through it for varying the circuits through four speeds being shown. ***For first speed*** 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′; this connects the two unit battery in parallel and the field windings of the two motors in series. A further movement of the controller, bringing the points, A, B, C, etc., into contact with A^2, B^2, C^2, etc., ***gives second speed,*** the batteries now being in parallel and the fields in series parallel. ***For third speed,*** the points B and C are brought into contact with B^3 and C^3, and E and F with E^3 and F^3, which means that the batteries are connected in series, and the fields in series. Similarly, for fourth speed, the points B and C are brought into contact with B^4 and C^4, and D, E, F, G, with D^4, E^4, F^4, G^4, which means that the batteries are in series and the fields in parallel. The connections between the battery, the armature brushes, and the motor fields, are made as indicated through the 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 Circuits.—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.

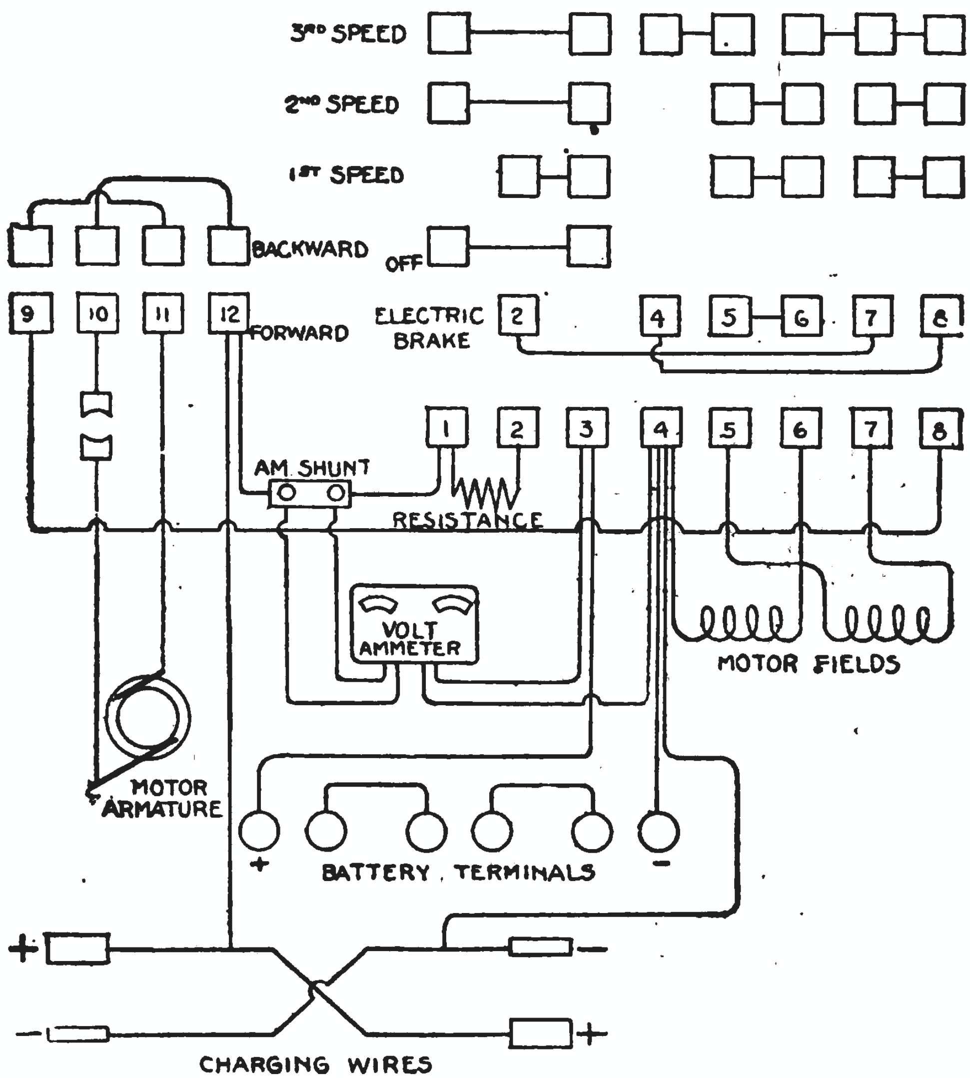


FIG. 4,097.—Diagram of controller connections of a one unit, one motor circuit, with variable fields.

The celis comprising the storage battery are so arranged as to form a number of unit, being so wired that by the use of a form of switch known as a controller, the connections may be varied from series to parallel, or the reverse, as desired. The same arrangement for varying the circuit connections is used for the field windings.

The wiring diagrams, ngs. 4,091 to 4,093, show one arrangement. 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.

Ques. How may the circuits be arranged with two batteries and two motors?

Ans. For this combination, as shown in figs. 4,102 to 4,104, it is possible to eliminate the resistance coil altogether and depend entirely upon the circuit shifting for regulating the

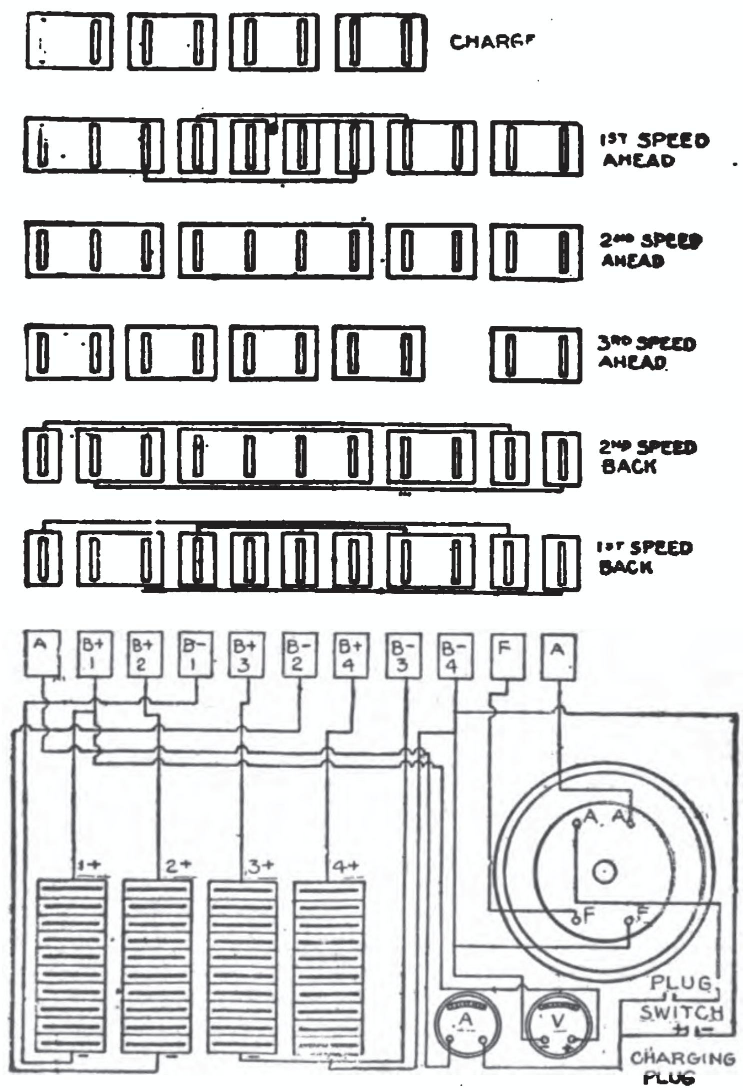
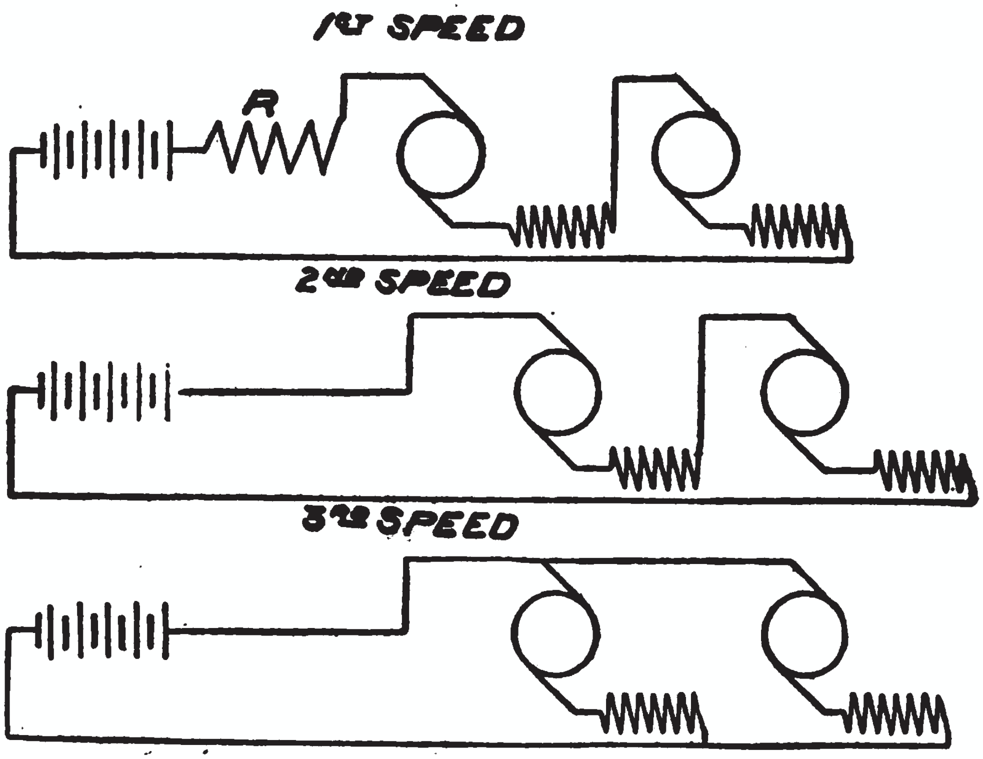
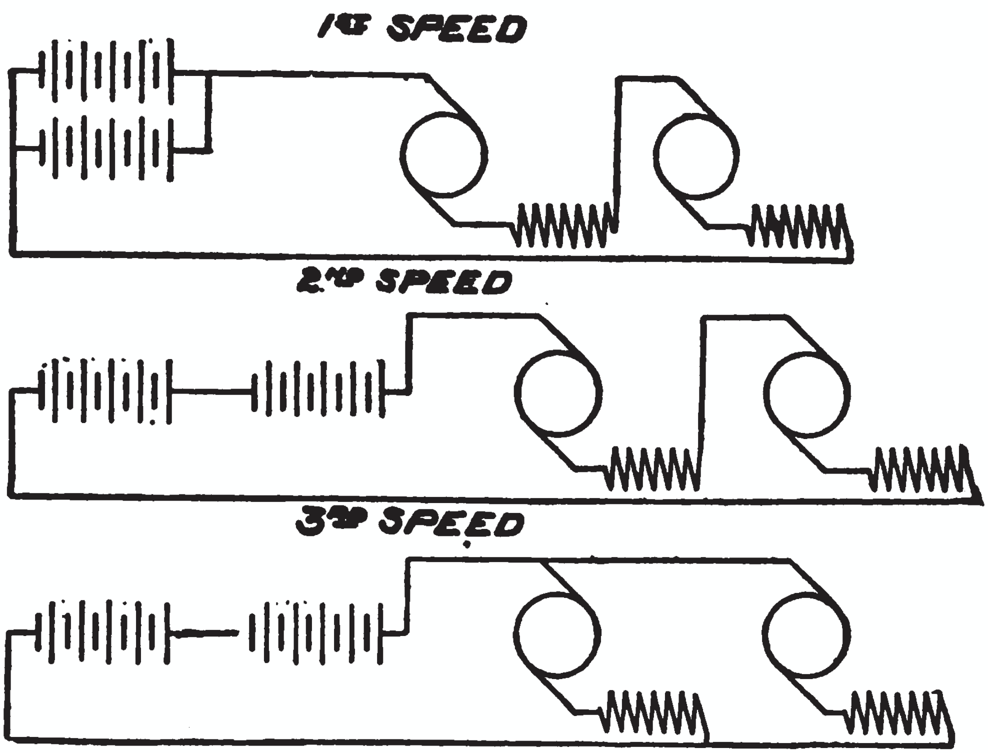


FIG. 4,098.—Diagram of controller connections of a four unit one motor circuit, with constant series connections for fields and armatures in forward and backward speeds.

voltage and power. Accordingly, *for the first speed* the batteries are connected in parallel, and the armatures and windings of the two motors in series. *For the second speed*, 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.



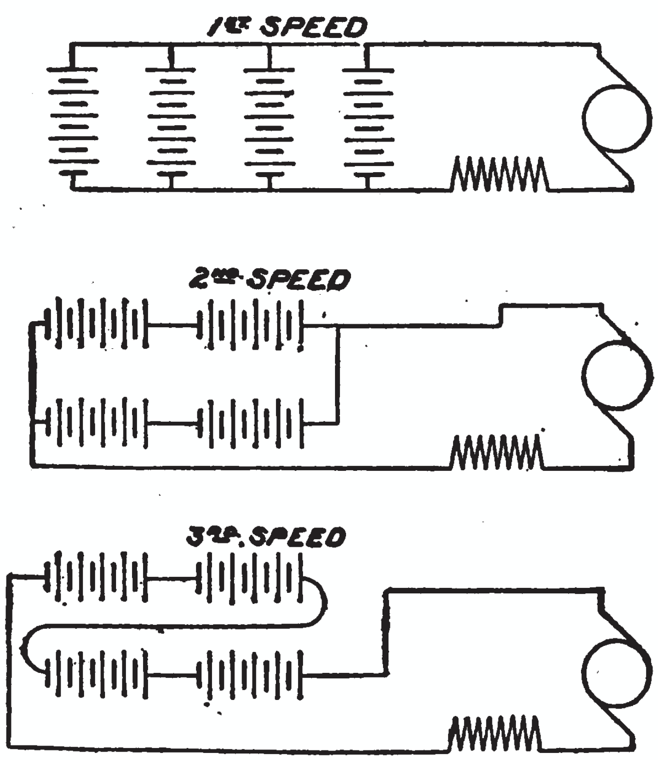
Figs. 4,099 to 4,101.—Diagrams showing methods of speed changing in a typical one battery unit, two motor circuit. ***The first speed*** shows the two motors in series, with a resistance coil interposed; ***the second,*** the motors in series, without the resistance; ***the third,*** the motors in parallel.



Figs. 4,102 to 4,104.—Diagram showing methods of speed changing in a two battery unit, two motor circuit, showing combinations for three speeds. ***The first speed*** is obtained with the battery units in parallel, 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 parallel.

How to Operate an Electric Vehicle.—The following instructions, which are given by one maker, will be found to apply for the most part to any car.

1. Be seated.
2. Place steering lever in position to give ready control.
3. Insert key in controller handle and unlock.
4. Pull controller handle back to brake or off position and raise slide. (This closes the circuit and electric is ready to move.)
5. Be sure that the foot brake is released.



FIGS. 4,105 to 4,107.—Diagrams showing combinations for three speeds in a typical four battery unit, single motor circuit. The only changes made in these circuits are in the battery connections. ***For the first speed*** the battery units are in parallel ***for the second,*** in series parallel, ***for the third,*** in series. The motor connections are not varied.

6. Forward movement of the controller handle gives two starting speeds and three running speeds.
7. To stop electric, pull controller handle backward past off position. First the electric brake will come into action and then a mechanical motor brake.
8. To reverse, bring electric to standstill. Press down the foot lever. Move controller handle forward same as when running forward. Two starting and one running speed will be obtained when backing.
9. To stop reversing, pull controller handle to extreme backward position. Take foot off reverse lever, which will automatically return

to forward position and electric is ready to be operated in a forward direction.

10. Steering: Push steering arm from you to turn to the left and pull steering arm toward you to turn to the right.

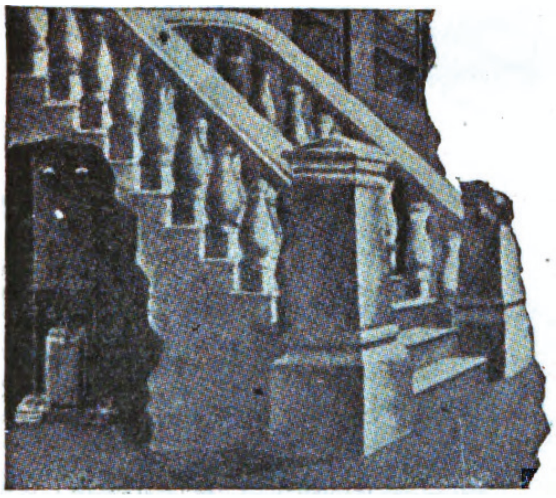
11. When leaving the electric, be sure to always force down slide of controller handle and take key out of lock.

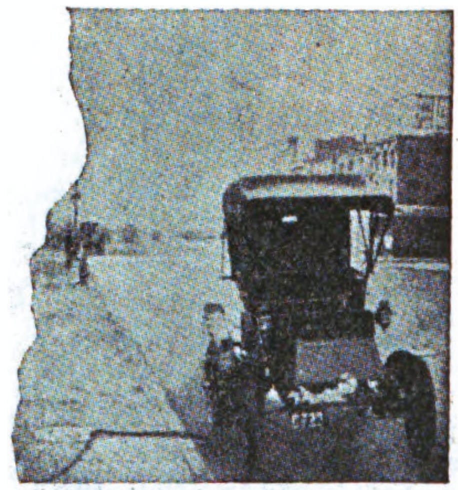
12. Release foot brake before applying power.

13. To charge batteries:

a. Be sure that slide of controller handle is down and key out of lock.

b. Insert charging plug in socket at rear of electric and if the connections from the plug to the charging source be correct the ammeter should show reading below the zero on the scale.





FIGS. 4,108 and 4,109.—Charging an electric in front of city residence; fig. 4,108 shows mercury rectifier located in basement under steps. With this arrangement the car may be charged at the curb during idle hours of the day.

c. Follow the instructions for charging and care of battery that are furnished by the manufacturers of the battery.

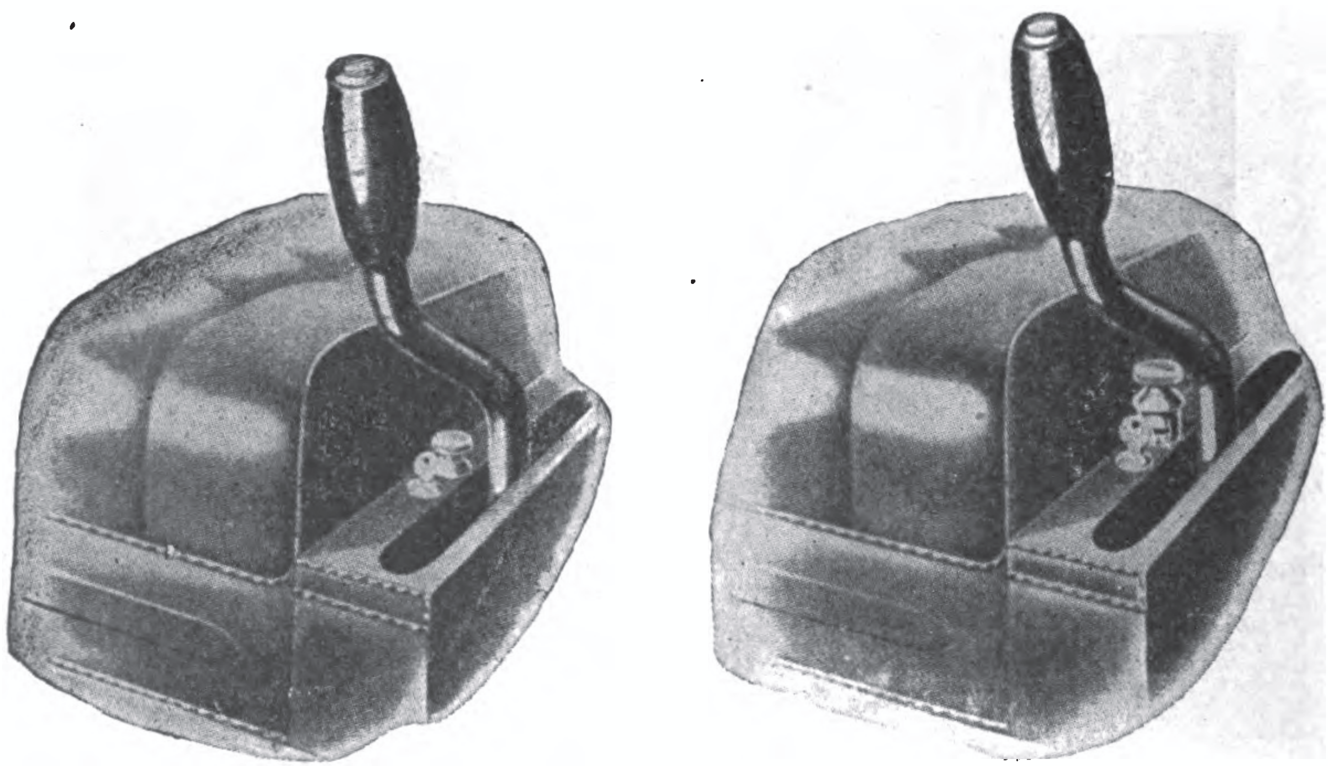
NOTE.—There are two push buttons in the floor of the car that may be operated by a slight pressure of the left foot. One increases the speed of the car and the other lights the meter lamp.

NOTE.—***Baker R and L motor and control.*** The motor is designed to receive the combined voltage of all the cells in the battery, *i. e.*, the battery is at all times in series and as the voltage is 2 volts per cell, the running voltage of the models equipped with 41 cells would be 82 volts and on those models having 42 cells the voltage would be 84 volts. The object of this is to eliminate the usual troubles caused by all unbalanced conditions of the battery as when several sections are operated in parallel. ***The first speed*** includes a high resistance and is intended for starting duty alone. ***The second speed*** has less resistance and although intended to grade the starting is convenient for occasional use in congested districts, but too slow for ordinary running. ***The next stop*** cuts out all the resistance and the motor runs on the series fields alone, the two sections being in series. ***The next or fourth speed*** parallels the two sections of series field. ***On the fifth speed*** the series fields are in parallel with an external shunt resistance across them. This weakens the strength of the series fields and reduces the resistance of the circuit. ***The sixth or highest speed*** of the car is obtained by means of an *accelerator button* located in the floor of the car. Its action is that of a switch closing the circuit of a light shunt field on the motor. The direction of the flow of current in this field is such that its strength opposes that of a series, thus weakening it and producing an increase of speed on light running; but due to the differential action between the two, a very great dropping off in speed occurs when climbing a grade or traveling a heavy road. In this manner great driving power and low current consumption is obtained on the grades on the high speed.

Electric Vehicle Troubles.—In order to properly cope with the numerous disorders and mishaps likely to be encountered, the following points relating to troubles may be found helpful.

1. If vehicle run too slow, look for the following:

a. Deflated tires.
b. Slow tires, due to other makes having been substituted for those furnished by the manufacturer of the vehicle.
c. Broken bearings in wheels, countershaft or motor.
d. Shoes not making perfect contact on face of controller.



FIGS. 4,110 and 4,111 Broc control lever lock. Fig. 4,110, locked, safety plunger pushed down; fig. 4,111, ready to operate safety plunger raised. ***To unlock,*** insert and turn the key, move control lever back to power off position, and pull up safety plunger.

e. Brushes not making perfect contact on commutator due to being too short, or commutator being dirty.
f. Broken battery jar, solution having partly leaked out.
g. Brakes rubbing when they are supposed to be thrown off.
h. Battery exhausted.

2. If the current be higher than usual when running on the level, look for the following:

a. Tight bearings.
b. Brakes rubbing.
c. Silent chains too tight.
d. Front wheels out of alignment.
e. Tires deflated.

3. If needle on ammeter vibrate more than usual, moving up and down very rapidly, look for the following:

a. Blackened commutator.
b. Commutator brushes worn too short.
c. Loose connections at battery terminals or at connections on controller.
d. Broken wire leading to meter.

4. If vehicle refuse to run, look for the following:

a. Broken jar in battery.
b. Broken connections between cells.

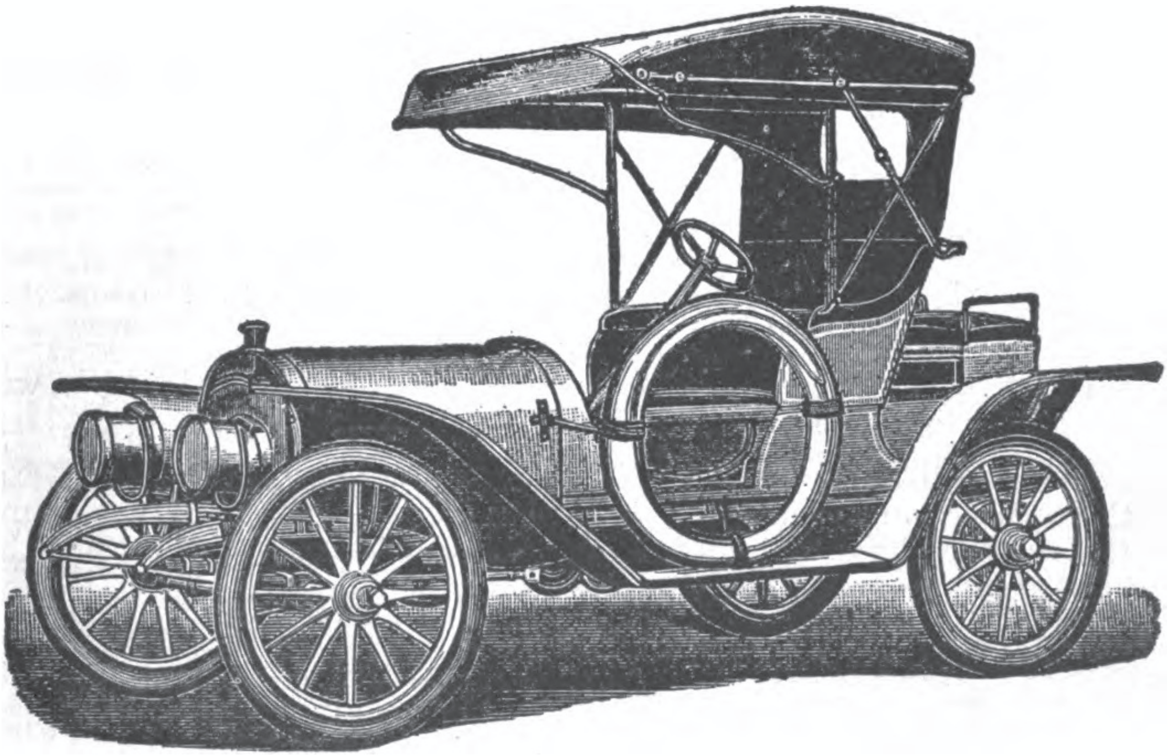


FIG. 4,112.—The Babcock electric roadster. This car is provided with a battery of forty two cells, which it is claimed, gives one hundred miles at seventeen miles per hour on one charge. The controller provides for five speeds forward and two reverse. The motor develops fifteen horse power, which will run the car over thirty miles per hour.

c. Broken terminals.
d. Open motor leads.
e. Broken connections on any part of vehicle.

5. In case vehicle do not run on any of the speeds, first examine those connections that are easiest to get at, viz:

a. Those at the end of the batteries.
b. The connecting straps, connecting one cell to another.
c. The wires going into the circuit closing switch.
d. The springs on the controller arm and the copper shoes. Be sure that they make contact with plates on the controller face.
e. See that there are no wires hanging loose, that appear to belong in the controller.
f. If the trouble be not found in some one of these points, it would be best to have an expert examine the machine.

6. If the usual graduation of speed be not obtained when running on the level, read carefully the instructions of maker relating to controller.

7. If ammeter on the vehicle do not register properly, look for the following:

a. Broken or partly broken connections in the wire leading from meter to shunt block, under floor of carriage.
b. The ammeter pointer sticking or working irregularly, due to dirt inside of ammeter, in which case it must go to the factory.

8. If the voltmeter do not register at all, look for broken connections in wires leading to connection points under floor.

9. If voltmeter read too high, there is something wrong inside; it should immediately be sent to the factory.

10. If the lights do not burn and the bell refuse to ring, look for a burnt fuse wire.

11. If one light refuse to burn while the others are working correctly try a new lamp, or examine connecting theater plug that connects body wiring to chassis wiring.

12. If both side lights refuse to burn, all other lamps being in working order, the trouble is in the connector.

13. If bell refuse to ring, all lamps being in working order, examine the theater plug connecting body and chassis wiring and make sure that the wires leading to the switch contacts at bottom of controller handle have not been taken out or broken off.

NOTE.—The bell can be tested by disconnecting from it the wires that are there, connecting two temporary wires to these same binding posts and touching these to the battery terminals. If the bell do not ring then it should be taken off and replaced with a new one or readjusted.

NOTE.—No meter on an electric vehicle is infallible as the service is very hard and the adjustments liable to get loose; and, as the general instructions as to care of battery, especially in charging, are to charge until voltage reads a certain amount, it is of the highest importance that the meter should read correctly. As soon as any irregularities are noticed in its readings, have it examined immediately by an expert, or send it to the factory. When it is necessary to return it to the factory, be sure to send the shunt block with it, as this is part of the meter. Even if no irregularities be noticed it would be well to have the meter examined at the factory and recalibrated once every year.