(No Model.)

3 Sheets—Sheet 1.

R. M. HUNTER.

ELECTRIC LOCOMOTIVE REGULATION.

No. 494,705. Patented Apr. 4, 1893.

FIG. 1

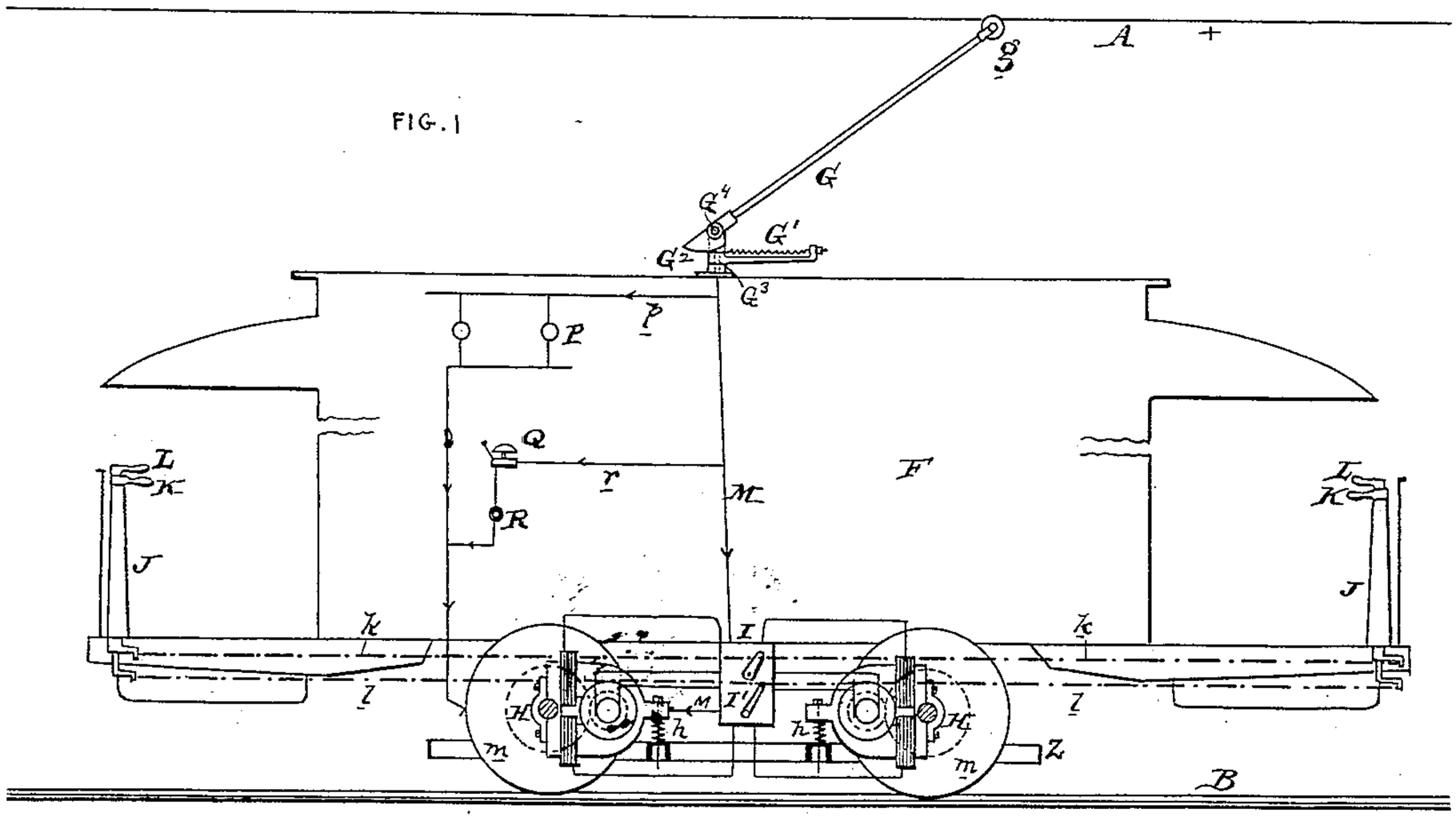


FIG. 2

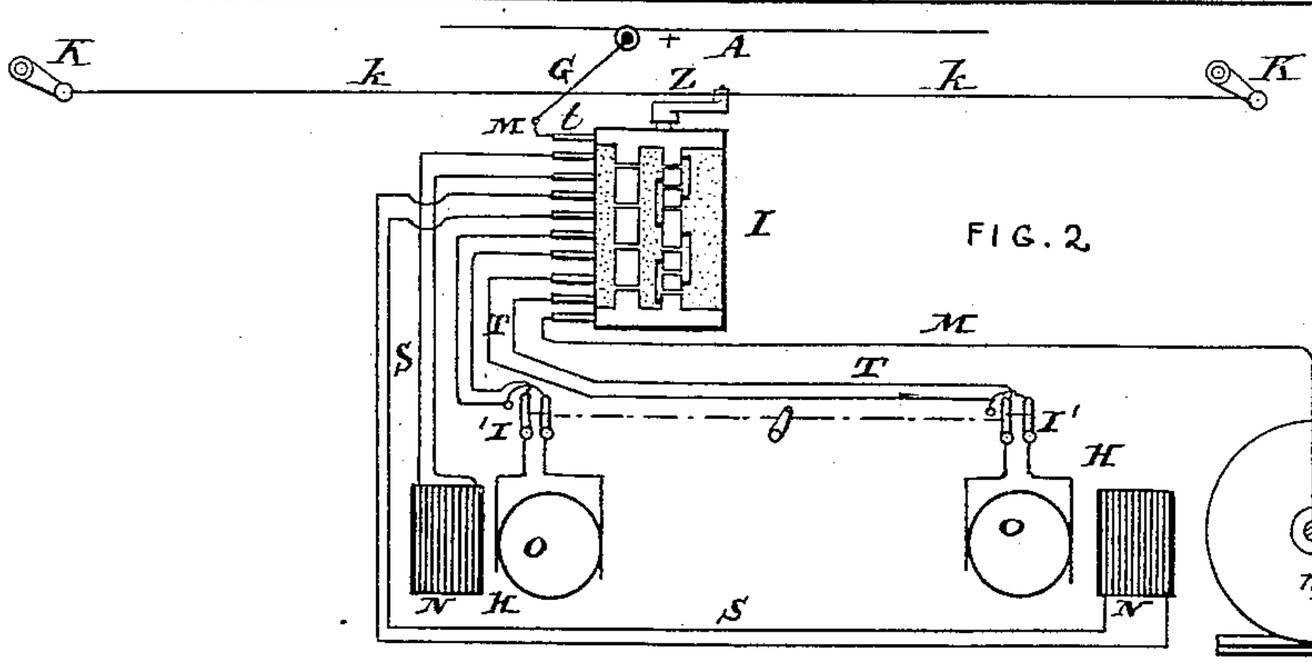


FIG. 4

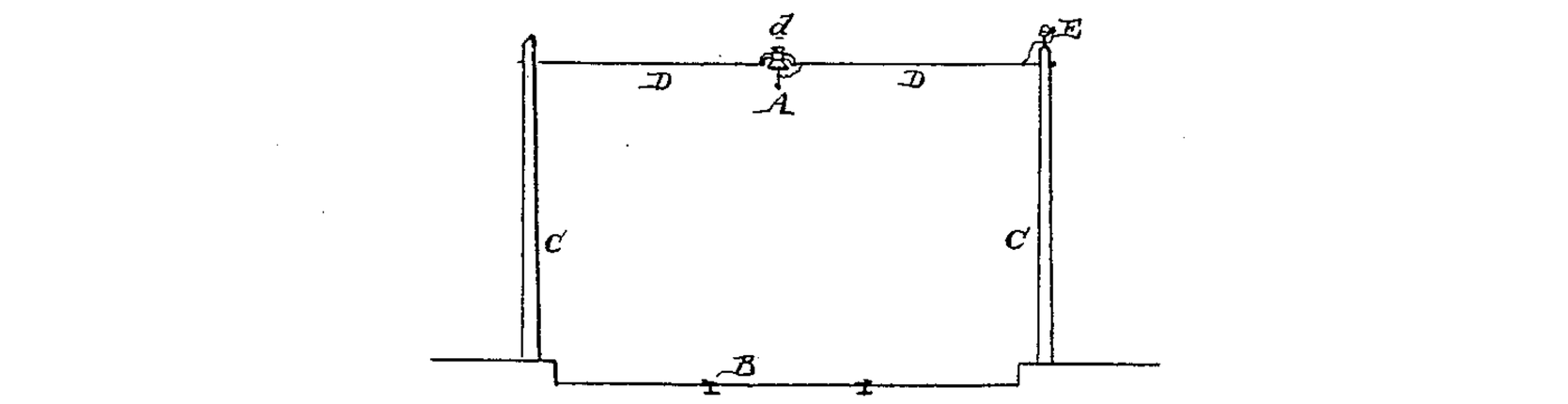
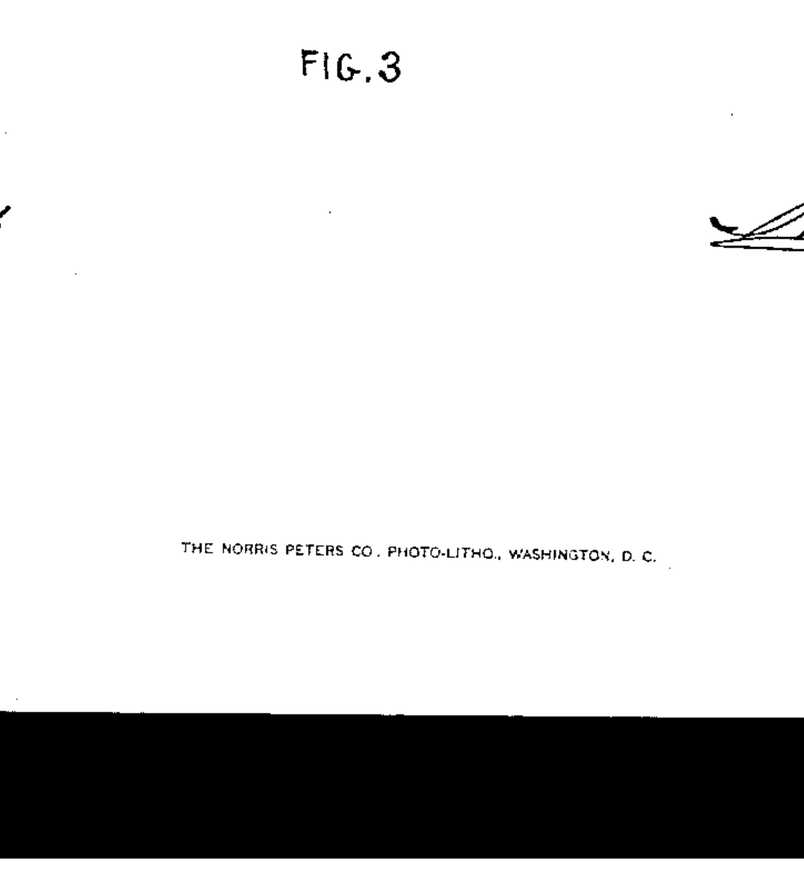


FIG. 3



Attest
Geo. B. Lauer.
C. M. Dieterich

Inventor
R. M. Hunter

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

(No Model.) 3 Sheets—Sheet 2.

R. M. HUNTER.

ELECTRIC LOCOMOTIVE REGULATION.

No. 494,705. Patented Apr. 4, 1893.

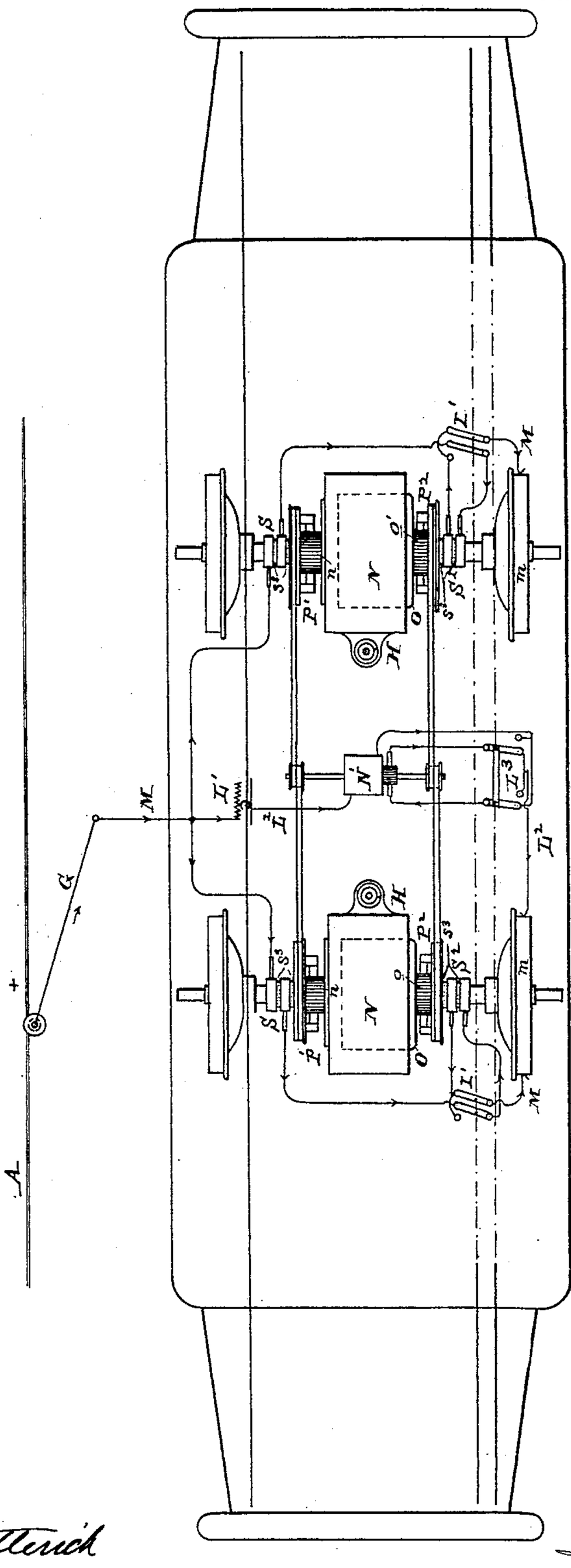


FIG. 5.

Attest
Geo. B. Lauer.
C. M. Dieterich

Inventor
R. M. Hunter

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

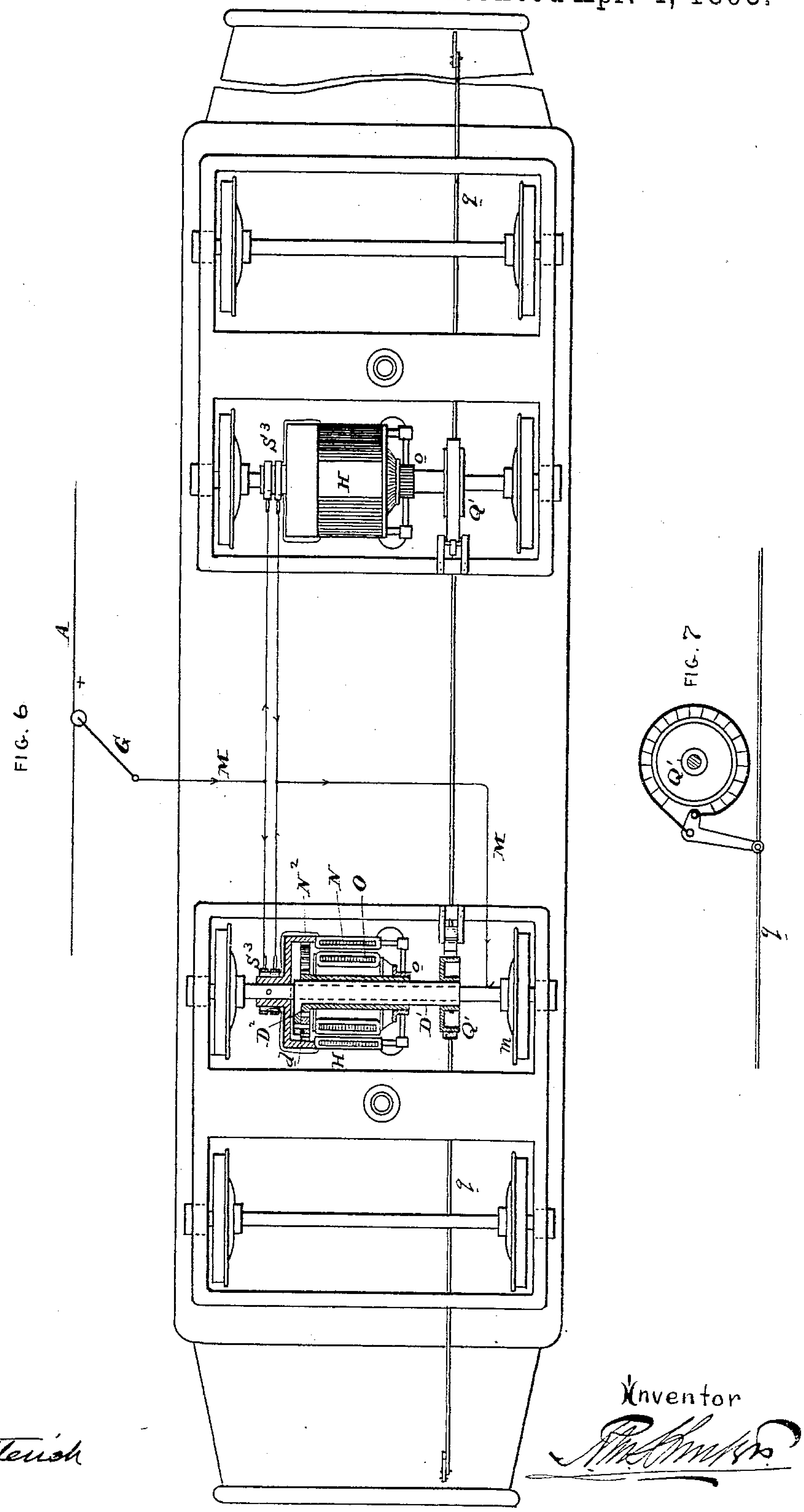
(No Model.)

3 Sheets—Sheet 3.

R. M. HUNTER.

ELECTRIC LOCOMOTIVE REGULATION.

No. 494,705. Patented Apr. 4, 1893.



Attest
Geo B. Lauer
C. M. Diettrich

Inventor
R. M. Hunter

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

RUDOLPH M. HUNTER, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO THE THOMSON-HOUSTON ELECTRIC COMPANY, OF CONNECTICUT.

ELECTRIC-LOCOMOTIVE REGULATION.

SPECIFICATION forming part of Letters Patent No. 494,705, dated April 4, 1893.

Application filed July 12, 1892. Serial No. 439,760. (No model.)

To all whom it may concern:

Be it known that I, RUDOLPH M. HUNTER, of the city and county of Philadelphia and State of Pennsylvania, have invented an Improvement in Electric Railways, of which the following is a specification.

My invention has reference to electric railways, and consists of certain improvements which are fully set forth in the following specification and shown in the accompanying drawings which form a part thereof.

This application, Case No. 222, has special reference to the method and means of supplying and regulating the electric current delivered from a stationary source to electric cars while in motion. Heretofore the common method of regulation for electric cars has been to employ a rheostat under the control of the motor man, with or without commutation of the field coils of the motor. The object has been to vary the resistance of the circuit, and thereby under Ohm's law vary the flow of current through the motor. It will be understood that this method of regulation is objectionable in that a complicated and expensive rheostat was necessary, and much of the electrical energy was dissipated in useless heat.

In carrying out my invention, I supply the current from a distant source by line conductors having a part arranged parallel to the railway track and with which a contact device on a traveling electrically propelled car makes electrical connection for the purpose of collecting and conveying current to the motors on the car. The current passes through the motors which are coupled so as to add their counter electro motive forces or otherwise vary the counter current to oppose the flow of current from the line, two motors at least being required for the most successful embodiment of my invention. The object is to vary the counter electro motive force of the motors inversely with the current required and power of the motor. For example, when starting the car from rest on a constant potential circuit, the counter electro motive force is reduced to that of one motor to overcome the inertia of the car at rest, and produce only that counter electro motive force as will not oppose the initial electro motive force too strongly, thereby permitting the necessary large flow of current. As the speed increases, the inductive reaction increases and the counter electro motive force also increases and reduces the current passing through the motors from the line conductor. It will thus be understood that within given speeds the regulation is automatic, but when the speed reaches that allowable in the streets, the counter electro motive force is not sufficient to arrest the flow of the current to the proper or desired degree unless the car is mounting a grade, at which time excessive duty is required of the motors and a large current necessary. If the car is on a level or no appreciable grade, and has reached its allowable speed, the counter electro motive forces of the motors are added to produce greater opposing effect to the flow of the line current. This opposes the initial electro motive force to such an extent that the required ampères alone pass through the motors at the difference of potential resulting from the opposing electro motive forces. The motors then maintain their normal speed on the level. The regulation is performed by varying the counter electro motive force of the motors inversely with the current required, and proportionally as the speed increases above the normal. By this method, no expensive or wasteful rheostats or resistances are required as heretofore. The motors should have their coils carefully calculated so as to give the proper counter electro motive forces for given speeds, and so as to work for proper regulation when coupled in parallel or series. In practice, I have found that the motors should be series motors or so grouped that the armatures are in series with the field coils whether the armatures be coupled in series or parallel with respect to each other. With shunt wound motors there is danger in that the armature offers so little resistance at starting it is liable to burn out before the motor can overcome the inertia of the loaded car, particularly on heavy grades. Again such method of winding has the objection of sluggish reaction and consequent slow generation of the counter electro motive force, which sluggishness is decidedly objectionable in this method of regulation. For these reasons, I prefer series wound motors worked in series or parallel and properly proportioned

and wound to give the desired counter electro motive force under special predetermined conditions as to speed and power.

In the drawings:—Figure 1 is an elevation of an electric railway and car embodying my improvements. Fig. 2 is a diagrammatic view showing the motors, circuits, and regulators. Fig. 3 is a cross section of an electric railway. Fig. 4 is a diagram representing a plan view of the railway circuits. Figs. 5 and 6 are plan views of other types of apparatus for carrying out my invention, and Fig. 7 is an elevation of the brake used in Fig. 6.

B is the railway track and acts as the return conductor.

A is the suspended working conductor arranged above the level of the track for supplying positive current to the cars F.

E are one or more supply conductors leading from the stationary source of electric energy, in the form of a dynamo electric machine W which may be located in a neighborhood where power can be obtained economically, and so constructed as to maintain a constant or substantially constant potential in the suspended conductor A. The rails B are also connected with the source of power W by leaders *e*. The supply conductors E may unite before reaching the generator W and be connected with it by leader *e*.

The supended working conductor A may be hung from insulators *d* on spanner wires D connected to poles C arranged on each side of the track. Any other suitable method of suspension may be employed. I do not confine myself to any position of the positive conductor, as its location, broadly considered, is immaterial. The same is also true of the return conductors.

Referring to Figs. 1 and 2, H, H, are two electric motors respectively geared to different axles to propel the car wheels *m* of said axles. Each of these motors is journaled upon an axle, and at the free end is supported by a spring connection *h* with a frame Z carried by the axle in any of the well known ways. The gearing between the motor and axle is shown by dotted lines. It is evident that any type of motor may be employed, and furthermore, may be gearless, or otherwise arranged to rotate the axle, as I do not limit myself to any particular method of arranging the motors to propel the car. The motors are preferably series motors and two or more in number. I is the motor regulator and is formed of a movable surface having contacts, as shown for instance in Fig. 2, which may be operated from either end of the car through rods *k* and cranks K supported in the standards J upon each platform, or by any other equivalent device. The regulator has a series of fixed contacts *t* which are respectively connected with the field coils and armatures of the motors, the trolley and the return contact. There are many ways of making the moving connection between the movable and fixed regulator contacts, that shown being given as a type. The regulator is formed of a cylinder I upon the surface of which are secured the contact blocks. This cylinder is moved by a crank arm Z, rods *k*, and cranks K, with respect to the stationary contacts *t*, which latter are in connection with the various terminals of the motors and sources of power as shown in Fig. 2. As the cylinder is moved to a greater or less distance, the motors may be put into circuit and coupled in series or parallel, as desired. When the left hand contact blocks are in connection with the terminal contacts the motors are coupled in circuit with the line and also in series with each other, that is, the armatures and fields of the two motors are in series; and when the regulator is moved to bring the right hand contact blocks into connection with the terminal contacts the motors are in parallel with each other, that is, the current divides and part passes through each motor. In both cases the current first traverses the field magnets and then the armatures so as to preferably keep the motors as series motors. M are the circuits leading from the trolley to the regulator I and from the regulator I to the wheels and axles *m* running in contact with the return conductor B. T T represent the circuits leading to the armatures O and include the two reversing switches I′ I′. S represents the circuits leading to the field coils of the two motors. These circuits T and S are made flexible so as to permit the motors to have the necessary independent motions without interfering with the electrical connection with the regulator. These circuits are clearly shown in Fig. 2. G is the trolley or current collecting device, and may be formed of any suitable construction, such for instance as illustrated in Fig. 1, which consists of an upwardly and rearwardly extending arm G pivoted to the car upon the universal joint G^2 so that its free end may swing vertically and laterally, and is pressed upward by a spring G′. Its upper end is provided with a grooved contact such as a wheel, making an under running contact with the under side of the suspended conductor. The collector may be reversible. The trolley shown is pivoted on the vertical axis G^3 arranged on the top of the car and shown in dotted lines, so as to permit the trolley to be completely reversed and trail toward either end. The arm G of the trolley arm is hinged on a transverse axis G^4 and is pressed upward by the spring G′ making its grooved roller *s* form an elastic under running contact with the under side of the suspended conductor A. Both of the reversing switches I′ are operated by the same devices, so that both motors are reversed at the same time. This reversing mechanism connects with both ends of the car by means of the rods *l* and the hand cranks L arranged upon each platform and journaled in the standards J.

It is immaterial to my invention what the details of the construction are for operating

the regulating and reversing mechanism from either end of the car as a large variety of means may be employed for this purpose. I have shown, however, a practical method of carrying out this part of the invention. P represents electric lamps included in multiple in a shunt circuit *p* arranged about the motors. Q is an electric bell or signal in a shunt circuit *r* provided with a switch R for causing it to operate. The generator W is preferably shunt or compound wound, and is of the constant potential type, varying the current for any requirement of the cars F which may be in circuit while maintaining a substantially constant electromotive force. It may be provided with a regulator X for varying the field strength. It will now be observed that the car is completely reversible so far as its running is concerned, and may be controlled from either end. The current collecting device G may be moved about its vertical axis so as to trail rearward, while devices K, L at either end of the car may be operated to control the motors according to which end of the car is the forward end. Ordinarily the handles would be removed from the rear end so as to prevent any possibility of interference with the operation from the forward end. By means of the current regulator I the counter electro motive forces may be reduced to that of one motor or that of the counter electro motive forces of the two motors, by the motors being thrown in series or parallel, or the motors may be cut out of circuit. This will be understood from the foregoing description, because it will be remembered that when the regulator had its surface moved to bring the left hand contact blocks into contact with the stationary terminal contacts *t*, the motors were in series in effect, and the counter electro motive forces of the two motors are added to check the flow of current from the line by opposing the initial electro motive force; and that when the contact surface was moved to bring its right hand contact blocks in connection with the fixed terminal contacts *t*, the coils of the motors were coupled in parallel and the counter electro motive force, last specified, was halved. Of course this counter electro motive force is constantly varying, and may be materially changed relatively for series or parallel connection by any variation in the speed. The regulation is not dependent upon the wire resistance except so far as that element may enter as a factor in the construction of any motor, but depends upon the electrical functions of the motors involving as an essential element the speed, since no counter electro motive force can be generated unless the motor has speed. At all times the armatures of the motors are preferably maintained in series with their respective field coils so that the motors are essentially series motors and at given speeds on constant potential circuits generate fixed counter electro motive forces. By this means the counter electro motive force may be varied to suit the requirements, and the use of external rheostats or resistances entirely obviated.

While in Figs. 1 and 2 I have shown the motors so that they may be coupled up to add their independent counter electro motive forces for regulation without varying the internal counter electro motive force of each motor otherwise than that which might be due to its own acceleration in speed, my invention is not so limited, as there are other ways of accomplishing a variation in the counter electro motive force without modifying or changing the connections of the motors.

In Fig. 5 I have shown a construction in which the motors are journaled upon the axles and have stationary field magnets and rotating armatures, which latter are secured to the axles. The field magnet N and the armature O are made substantially alike and are provided respectively with the commutators *n* and *o*. P′ represents the revolving brushes for the field magnet commutator and P^2 represent revolving brushes for the armature commutator. The commutators or brushes of field magnets are arranged with respect to the similar parts of the armature so as to cause the poles of the field magnet to be at an angle to the poles of the armature. The current passes from the current collector G over the circuit M through the collector rings S and field magnet brushes P′, thence to the collector rings S^2 and brushes P^2 of the armature, and finally to the rails B through the wheels *m*. The field magnets in Fig. 5 are supported loosely upon the axle as is customary in electric cars with gearless motors, and the armatures are firmly secured to the axles in any suitable manner and rotate with them. The brushes P′ for the field magnets, and P^2 for the armatures are carried upon a rotating sleeve S^3 journaled concentrically with the armature, and these by means of the belts and motor N′ are rotated. They are series motors having the armature in series with the field. The current first passes through the field and then through the armature. The armature current may be reversed by the reversing switches I′. N′ is a small electric motor which through chains and sprocket wheels rotates the field and armature brushes at any speed desired. This motor N′ is in a shunt circuit L^2 and is provided with a regulator L′ which may be operated from either end of the car. A reversing switch L^3 may be used for reversing the motor N′. The reversing switches for all of the motors may be also operated from either end of the car. The two propelling motors are similar in construction, and may be controlled by the same regulator motor N′. With this construction the speed of the armature is controlled by the counter electro motive force which is generated in the motor, and is regulated by the speed imparted to the revolving brushes. If the brushes are revolved with sufficient rapidity a sufficient counter electro motive force may be produced

in the motors to arrest all flow of current from the line conductors due to the initial electro motive force, and in this case the motors will be at rest. By varying the speed of the brushes the counter electro motive force may be varied, and the desired flow of current controlled to change the speed and power of the motors without in the least changing the resistance of the motor circuits on the car.

A still further method of carrying out my invention is illustrated in Fig. 6 in which we have the two motors H sleeved respectively upon one axle of each of two pivoted trucks. The field magnets N are secured fast to the axle while the armatures O are sleeved and free to revolve thereon. A sleeve D′ carries a pinion *d* which works in connection with a spur wheel D^2 upon the armature and an internal gear N^2 upon the field magnets. The current in the field magnets is obtained from the motor circuit M by means of collector rings S^3. The armature is provided with a commutator *o*. The armature brushes are carried with the field magnets N so as to travel around the commutator *o* at a speed commensurate with the travel of the field magnets. If the sleeve D′ be permitted to revolve freely the armature O will have no work to perform and will be moving at its highest speed producing a counter electro motive force sufficient to arrest the flow of current from the line. If now it is intended to start the car into motion, a friction brake Q′ is applied to the sleeve B′, gradually arresting its rotation. This friction brake is adapted to be operated from either end of the car by rod *q*. One type of this friction brake is clearly shown in Fig. 7 and is of a well known construction. As the sleeve D′ and pinion *d* slow down in their travel about the axle, the field magnets begin rotation in an opposite direction to the rotation of the armature but the relative speed is much slower as there is work being performed, and consequently the counter electro motive force is reduced, permitting the current from the line to flow through the motors sufficiently to accomplish the desired speed. As the inertia is overcome, the relative speeds of the armature and field magnets increase and the counter electro motive force increases to reduce the flow of current to compensate for the reduced work to be performed. If the speed is to be great with a load this sleeve D′ and its pinion may be held at rest and the car will then be traveling at its maximum speed and with a counter electro motive force adequate to arrest all flow of current but that necessary to the duty. When it is desired to stop the car, the brake Q′ is thrown off and the armature revolves rapidly without performing work except to generate a counter current which shall have an electro motive force equal to and to balance the initial electro motive force of the line. The circuits in the cases of Figs. 5 and 6 are flexible as in the case of the construction shown in Fig. 1. These examples will illustrate the principles of the invention which eliminates the varying resistance principle of regulation heretofore commonly used in electric railway practice.

I do not limit myself to the minor details as they may be modified in various ways without departing from the principles of my invention.

Having now described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an electric railway, the combination of a working conductor extending along the railway and insulated from the ground, a stationary source of electric energy for supplying a current of constant potential and varying current to the said working conductor, a series of electric cars each of which is provided with two or more electric motors adapted respectively to rotate independent axles, a current collecting device carried with each car and making contact with the working conductor, motor circuits upon each of the cars, controlling mechanism on each car adapted to be operated from the end of the car for controlling the counter electro motive force of the motors simultaneously, and a return rail circuit leading to the stationary source of supply, whereby all of the cars may receive current from the same source and have the current passing through the motors of the respective cars controlled by independently varying the counter electro motive force of the said motors of the different cars.

2. In an electric railway, the combination of a working conductor extending along the railway and insulated from the ground, a stationary source of electric energy for supplying a current of constant potential and varying current, one or more supply conductors leading from the source of constant potential current and connecting with the working conductor at one or more places in its length to reduce the resistance and maintain as far as possible the potential of the working conductor uniform, a series of electric cars each of which is provided with two or more electric motors adapted respectively to rotate independent axles, a current collecting device carried by each car and making contact with the working conductor, motor circuits upon each car, controlling mechanism on each car adapted to be operated from the end of the car for controlling the counter electro motive force of the motors simultaneously, and a return circuit leading to the stationary source of supply, whereby all of the cars may receive current from the same source and have the current passing through the motors of the respective cars controlled by independently varying the counter electro motive force of the said motors of the different cars.

3. In an electric railway, the combination of a working conductor extending along the railway and insulated from the ground, a stationary source of electric energy for supplying a current of constant potential and varying current to the said working conductor, a

series of electric cars each of which is provided with two or more electric motors adapted respectively to rotate independent axles, a current collecting device carried with each car and making contact with the working conductor, motor circuits upon each of the cars, controlling machanism on each car adapted to be operated from the end of the car for controlling the counter electro motive force of the motors simultaneously, a return circuit leading to the stationary source of supply, whereby all of the cars may receive current from the same source and have the current passing through the motors of the respective cars controlled by independently varying the counter electro motive force of the said motors of the different cars, and a switch also adapted to be operated from the end of the car for reversing the motors simultaneously.

4. In an electric railway, the combination of a working conductor extending along the railway, a source of constant potential current connecting with the said suspended conductor, an electrically propelled vehicle having two or more electric motors adapted respectively to rotate independent axles, a current collecting device making contact with the working conductor for supplying the current to the car, motor circuits extending from the contact device and including the motors, regulating means carried by the car and extending to both ends thereof for coupling the motors in series or parallel to vary the counter electro motive force, and a return circuit leading from the car to the source of electric energy.

5. In an electric railway, the combination of a working conductor extending along the railway, a source of constant potential current connecting with the said suspended conductor, an electrically propelled vehicle having two or more electric motors adapted respectively to rotate independent axles, a current collecting device making contact with the working conductor for supplying current to the car, motor circuits extending from the contact device and including the motors, regulating means carried by the car and extending to both ends thereof for controlling the counter electro motive force of both motors simultaneously, means to reverse both of the electric motors extending to both ends of the car, and a return circuit leading from the car to the source of electric energy.

6. The combination of a suspended working conductor extending along a railway and above the car, in combination with an electrically propelled car having two or more electric motors connected to rotate its axle, an upwardly extending vertically and laterally movable current collecting device having its weight carried by the car and making an under running contact with the suspended conductor, a motor circuit connecting the current collecting device with the rails and including both electric motors, a source of electric energy connected with the suspended conductor and the rails, and a current regulator adapted to be operated from the end of the car for controlling the counter electro motive force of both motors simultaneously.

7. The combination of a suspended working conductor extending along a railway and above the car, in combination with an electrically propelled car having two or more electric motors connected to rotate its axles, an upwardly extending vertically and laterally movable current collecting device having its weight carried by the car and making an under running contact with the suspended conductor and reversible so as to trail in either direction in the line of travel of the car, a motor circuit connecting the current collecting device with the rails and including both electric motors, a source of electric energy connected with the suspended conductor and the rails, and a current regulator adapted to be operated from either end of the car to simultaneously vary the counter electro motive force produced by both motors.

8. In an electric railway, the combination of the rails acting as the return conductor, a suspended conductor arranged above the car and parallel to the railway, an electrically propelled car, an upwardly extending current collecting device having its weight carried by the carbody and making an under running contact with the suspended conductor, two electric motors on the car for propelling the same journaled upon the respective axles and spring supported at their free ends upon a frame carried by the axles, a regulator upon the carbody for coupling the motors in series or parallel, a circuit from the current collecting device to the regulator, flexible circuits from the two motors to the regulator whereby the motors may have movements independent of the regulator without interfering with the electrical circuits, a circuit connecting with the rails which act as the return circuit, and means extending to the end of the car for operating the regulator for the purpose of varying the counter electro motive force of the motors for changing the speed of the car.

9. In an electric railway, the combination of the rails acting as the return conductor, a suspended conductor arranged above the car and parallel to the railway, an electrically propelled car, a current collecting device having its weight carried by the carbody and making an under running contact with the suspended conductor, two electric motors on the car for propelling the same journaled upon the respective axles and spring supported at their free ends upon the frame carried by the axles, a regulator upon the carbody for coupling the motors in series or parallel, to vary the counter electro motive force, a circuit from the current collecting device to the regulator, flexible circuits from the two motors to the regulator whereby the motors may have movements independent of the regulator without interfering with the electrical connections, a circuit connecting with the rails which

act as the return circuit, means extending to the end of the car for operating the regulator to vary the counter electro motive force of the motors in varying the speed of the car, and an independent switch for reversing the motors also extending to the end of the car.

10. The combination of a vehicle, two or more electric motors upon the vehicle to propel it, a source of electric energy of constant potential, means controllable by hand for varying the counter electro motive force of the motors, and electric circuits for putting the electric motors in electrical connection with the source of electric energy and maintaining at all times the armatures in fixed series working relation with the field magnets and the individual counter electro motive forces of the several motors equal or substantially equal.

In testimony of which invention I have hereunto set my hand.

RUDOLPH M. HUNTER.

Witnesses:

ERNEST HOWARD HUNTER,

S. T. YERKES.