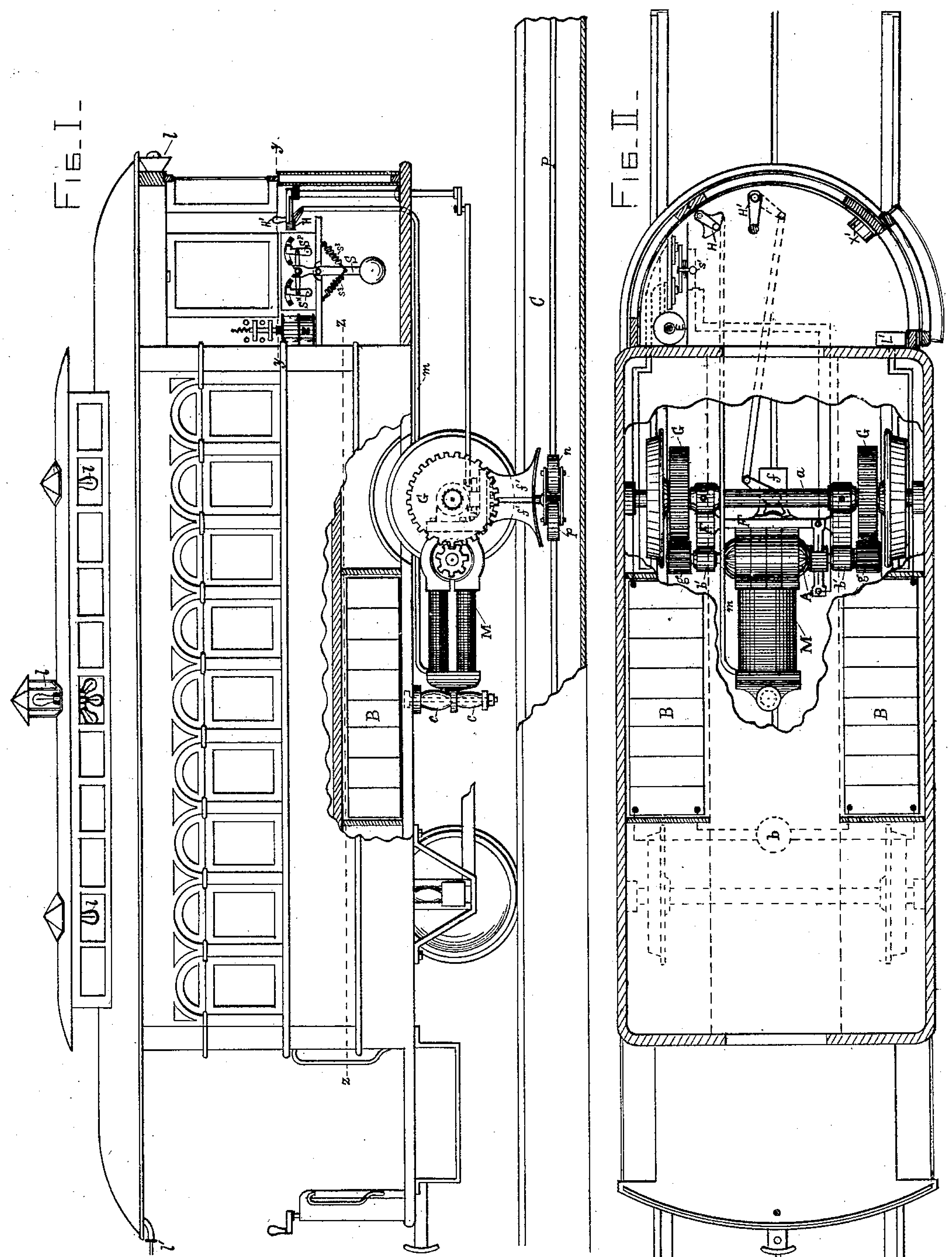
(No Model.) 3 Sheets—Sheet 1.

E. E. RIES.

METHOD OF OPERATING ELECTRIC RAILWAYS.

No. 417,338. **Patented Dec. 17, 1889.**



WITNESSES
Eva Ries.
J. Kann

INVENTOR
Elias E. Ries
by Attorneys
Harding & Tichenor

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.) 3 Sheets—Sheet 2.

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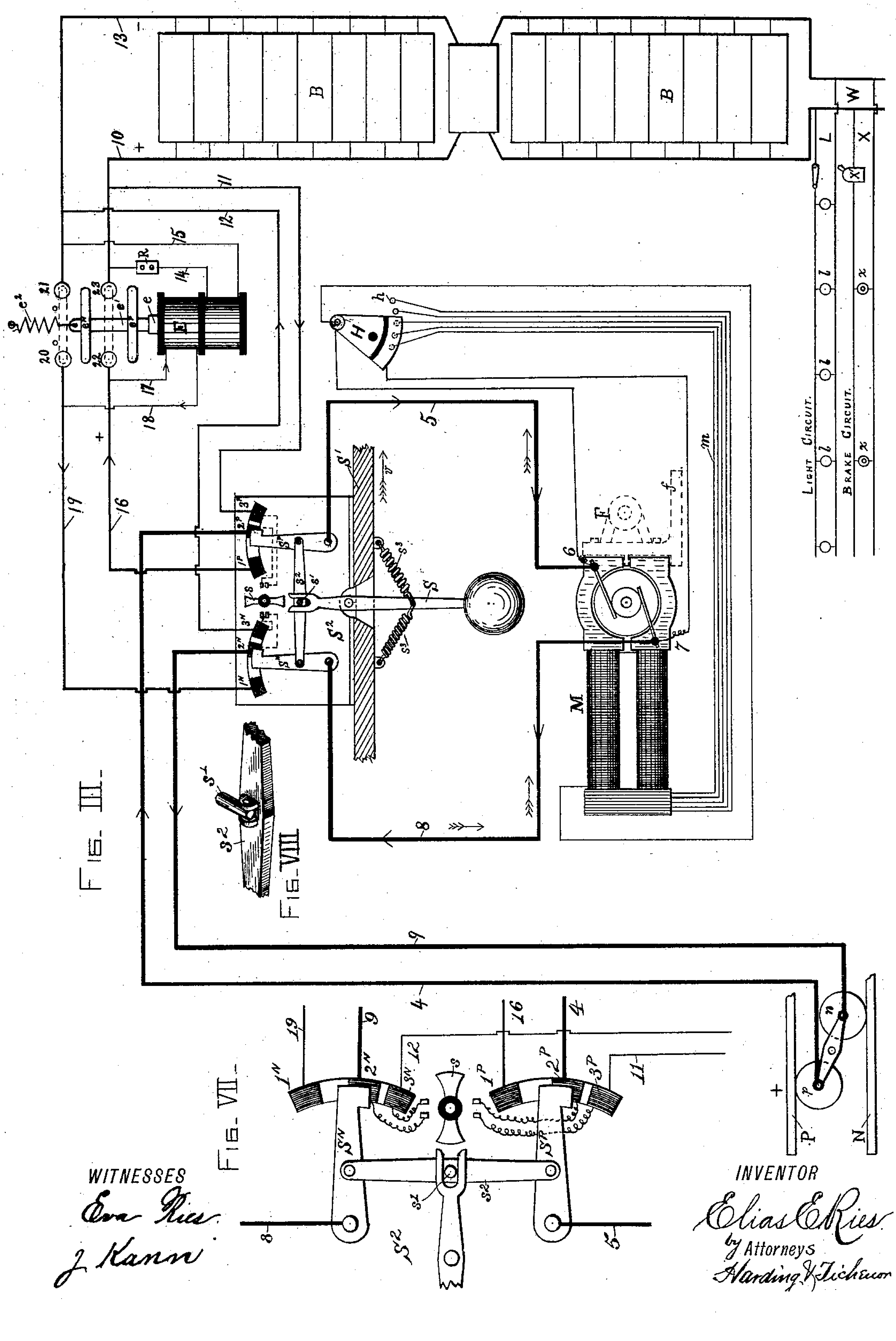

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J. Kann

INVENTOR
Elias E. Ries
by Attorneys
Harding & Tichenor

N. PETERS, Photo-Lithographer, Washington, D. C.

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Fig IV.

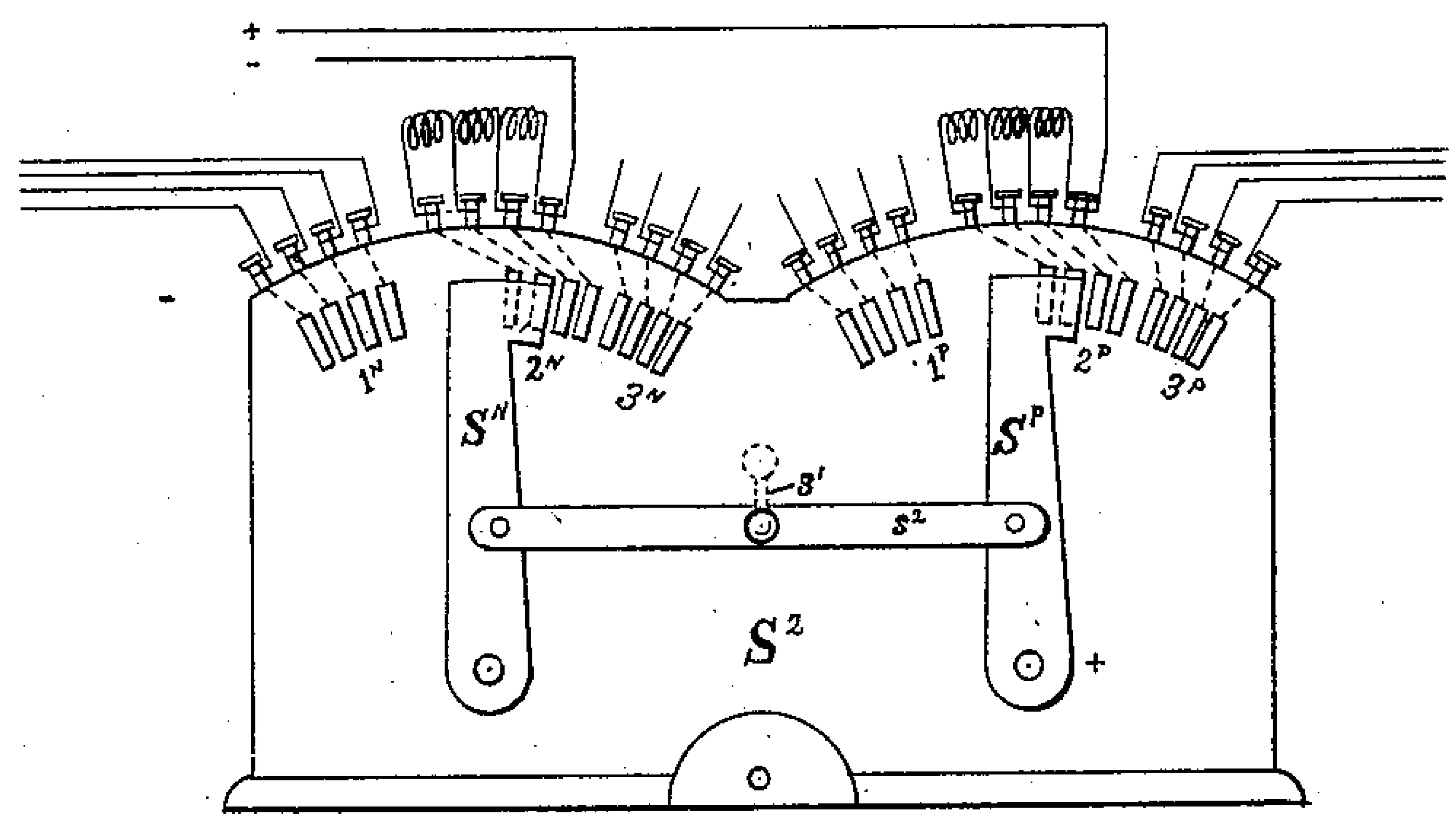


Fig V.

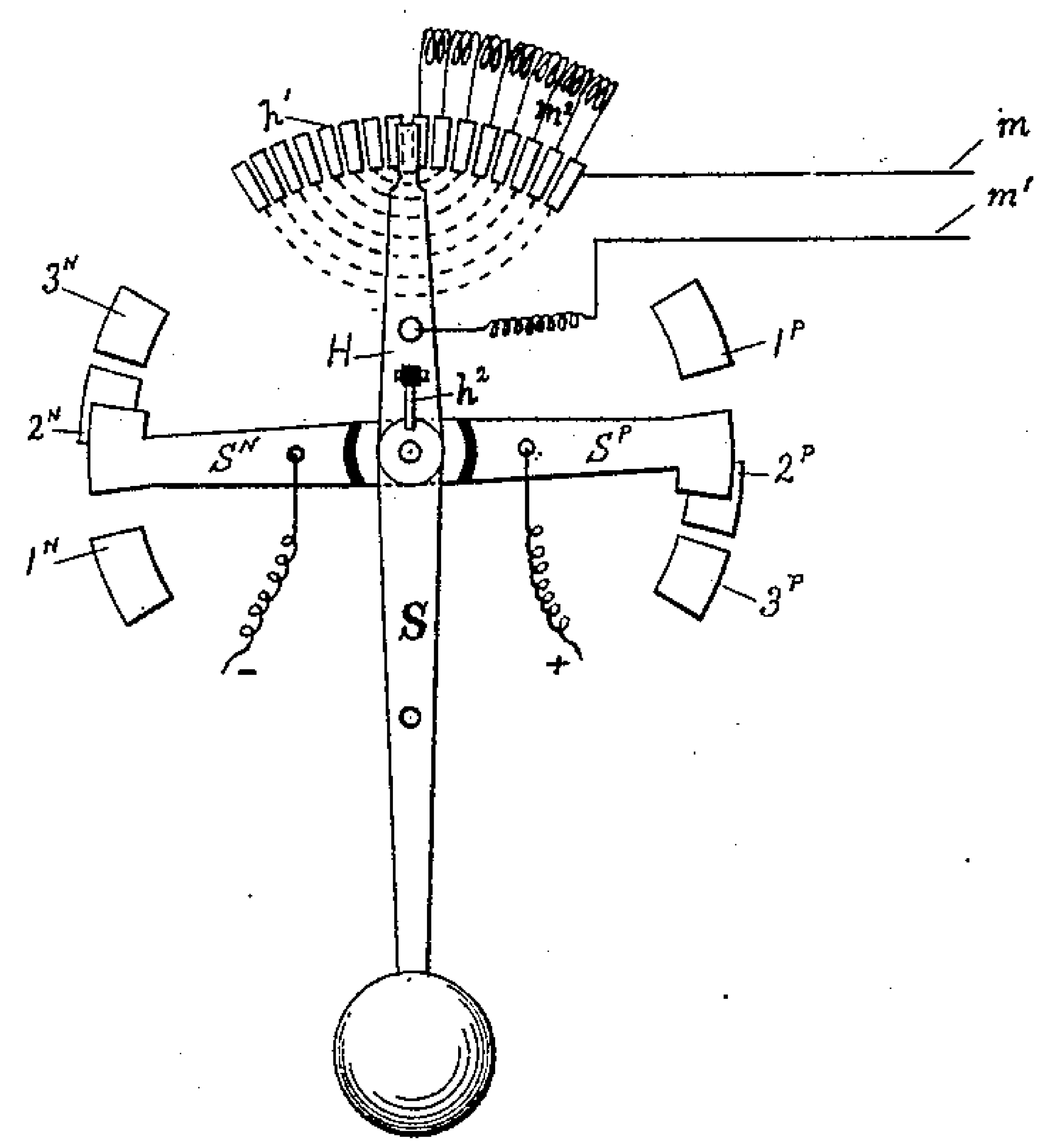
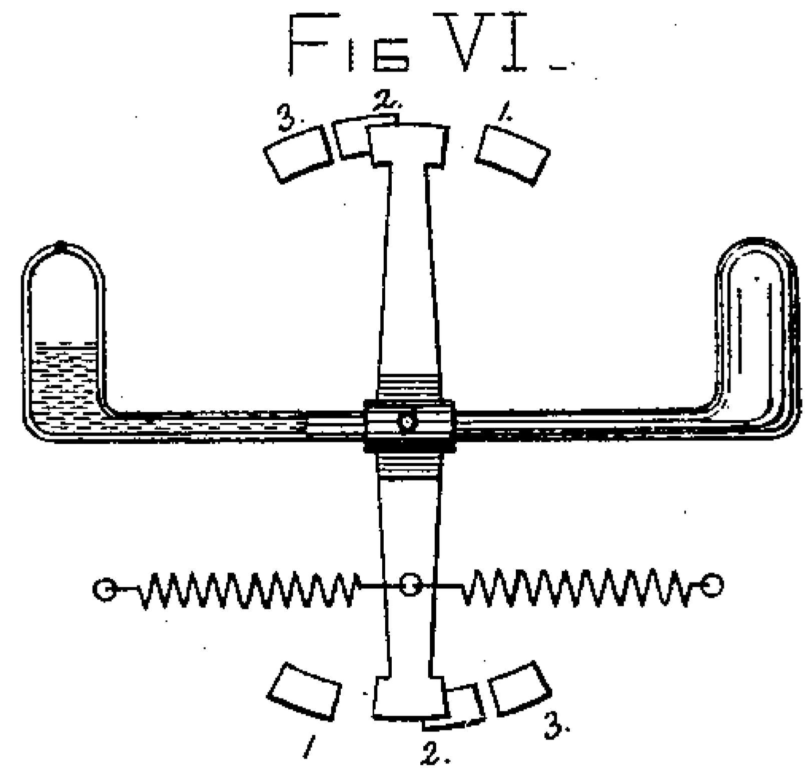


Fig VI.



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Eva Ries.
J. Kann

INVENTOR
Elias E. Ries,
by Attorneys
Harding & Tichenor

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

ELIAS E. RIES, OF BALTIMORE, MARYLAND, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, TO RIES & HENDERSON, OF SAME PLACE.

METHOD OF OPERATING ELECTRIC RAILWAYS.

SPECIFICATION forming part of Letters Patent No. 417,338, dated December 17, 1889.

Application filed June 22, 1886. Serial No. 205,941. (No model.)

To all whom it may concern:

Be it known that I, ELIAS E. RIES, of the city of Baltimore, and State of Maryland, have invented certain new and useful Improvements in Methods of Operating Electric Railways, of which the following is a specification.

This invention relates to certain improvements in electric railways of that class in which the propelling-current is conveyed to the motors or cars by means of electrical conductors extending along the line of the railway; and its object is to provide an economical, efficient, and practical system for the more thorough and effective utilization of electricity in the operation of such railways.

In explanation of the fundamental principle of my invention I will designate the same as one of the many varieties and forms of what I term a "combination system," which embraces, essentially, the idea of providing electrically-propelled vehicles with storage-batteries, which latter derive current from line-conductors and, under certain conditions, co-operate with and re-enforce the said line-current. Other forms of this combination system constitute the subject-matter of several concurrent applications, and therefore they will not be further dwelt upon herein.

In the present case the secondary battery is charged not by a portion of the main-line current, but by the action of the motor itself when the car is descending a grade or when its motion is about to be arrested, at which times the motor by this invention acts as a generator and stores up energy in the secondary battery, which is given out again to assist the main-line current in propelling the car when it is ascending a grade. Furthermore, provision is made whereby the motion of the car can be arrested in any desired space of time by the same means, so that, if desired, other braking devices may be entirely dispensed with.

My invention is equally applicable to electric railways in which the cars are run singly, as on street or surface railways, or in trains, as they are generally run on elevated and other railways. It is also applicable to electric cars which depend altogether upon accumulators for their propelling-current.

Heretofore it has been necessary in all railway systems, whether operated by electricity or any other motive power, to provide sufficient power not only to propel the cars or trains of cars over the level portions of the railway at the desired rate of speed, but also to overcome their inertia in starting and to surmount the various gradients that present themselves. It is well known that the amount of power expended in starting a train and bringing it to full speed is greatly in excess of that required to maintain it under headway when once in full motion, and also that a similar and oftentimes much larger addition to the normal propelling-power is required to ascend ordinary grades, such as are met with on nearly all railways. On the other hand, it is also known that the additional power so expended in moving a train is stored up in the train itself in the form of energy, which manifests itself as momentum when the propelling-power is cut off on level grades, and in the form of accelerated motion on downgrades. The amount of this energy available for useful work is exactly equivalent to that originally expended in bringing the train under headway and in lifting it to the height at which it begins to fall less the loss due to friction and conversion, which is, or need be, comparatively small. This useful energy, however, is, in the the majority of cases, not only entirely wasted, but an additional loss is actually occasioned in opposing or retarding the motion of the train due to such energy by the further application of power to operate the brake apparatus whenever it becomes necessary to stop the train or to reduce its speed on a descending grade, and thus not only wasting the original energy stored up in the train, but checking or neutralizing it by the expenditure of additional power and at the expense of the car-wheels and brake apparatus. By means of the present invention this energy of the train is automatically transformed into electrical energy, which is stored in secondary batteries or accumulators, as before mentioned, and is utilized at the proper time to give back its energy to the train when it is most required, by assisting the main propelling-power in overcoming the inertia of the train and in ascending the grades. In this manner a line of railway having any number of grades may be operated with considerable more economy and less waste of power than a perfectly-level road of the same length and working conditions could be under the systems at present in use, and the amount of power required to operate the road would be but slightly in excess of that required to keep the cars or trains in motion on a level, this slight amount being added to compensate for the natural loss due to converting the mechanical energy of the train into electrical energy, and vice versa. Besides utilizing the energy of the car or train for charging a secondary battery, means are provided for regulating the charging process and at the same time enabling the train to be brought to a stop in any desired space of time without the employment of special brake devices, and also for utilizing a portion of the stored energy for lighting the train by electricity, and for other purposes.

In the organization of apparatus hereinafter described the various processes of charging and discharging, &c., are performed automatically, but of course any other arrangement may be employed, if preferred, without departing from the spirit of this invention. Neither do I limit myself to the particular forms of automatic switching devices shown, as there are other ways of attaining the desired result, some of which will be referred to hereinafter.

Referring to the drawings, Figure I is a side elevation, partly in section, of an underground conduit and a car provided with current-collectors, electro-dynamic motor secondary battery, and switching devices arranged in accordance with my present invention. Fig. II is a plan view of the car shown in Fig. I, taken on lines *y y* and *z z*, respectively, with a portion of the flooring broken away. Fig. III is a diagram view illustrating the electrical connections and the arrangement of circuits and switches employed, and showing one form of automatic switching apparatus for changing the circuits according to the inclination of the car. Fig. IV is a detail view of a portion of the switching apparatus shown in Fig. III, with its terminal plates subdivided. Fig. V is a modified form of automatic switching and regulating apparatus. Fig. VI is a modification showing a different form of gravity-switch. Fig. VII is a detail view of a supplemental switch and its connections for connecting the storage-battery in the line-circuit independently of the motor-switches. Fig. VIII is a detail view showing the pivoted pin *s'*.

It has already been proposed (see Patent No. 318,668, May 26, 1885) to employ the energy of a moving train on an electric railway for braking the train by converting the motor into a generator for the time being, and also for supplying the line-conductors with extra current, designed to assist other motors along the line. This plan contemplates increasing the counter electro-motive force of the motor until it exceeds the direct electro-motive force of the line, thereby causing it to act as a generating-dynamo to arrest the motion of the train and at the same time send a portion of the generated current to the line. This plan, however, while it may serve the purpose of braking the train, has certain disadvantages which it is part of the object of the present invention to overcome. These disadvantages arise from the fact that a large portion of the energy of the moving train is consumed in overcoming the direct and presumably-constant electro-motive force of the line before any useful current can be gained or the progress of the train retarded; second, the counter electro-motive force developed by the motor or motors of the moving train must first counteract or neutralize the direct-line current, and therefore diminish, for the time being, instead of increasing the supply of current flowing to other motors from the generating station or stations; third, whatever current is gained by the line would be distributed over its entire length and divided between all the motors instead of being directly applied to the particular motor that may at that moment most require it. Several other objections of a similar nature might be cited, but the examples given will suffice. According to my present invention these objections are removed, as will hereinafter more fully appear, by interrupting the connection between the line-conductors and the motor and closing that between the motor and secondary battery when the said motor is acting as a generator, and by means of certain other features, which will shortly be described.

In the accompanying drawings the invention is shown as applied to an ordinary street or passenger car, whose propelling-current is derived from conductors carried in an underground conduit.

C is the conduit; M, the motor; B, the battery, and S the switching devices.

The conduit and the current-collecting devices illustrated in the present drawings are substantially the same as those shown in my previous application for Letters Patent, filed January 25, 1886, Serial No. 189,631, to which reference should be had for a complete description. In the present instance the guide-brackets *f' f'*, between which the bar carrying the current-collecting devices enters the conduit-slot, are secured to a projecting portion *f* of the frame F, directly under the center of the driving-axle *a*.

The motor M, which is of the reversible type, is supported at one end from the car-body by means of rubber springs or cushions *c c*, and at its other extremity is firmly secured to a frame F, which is pivoted to the driving-axle *a*, as shown, and which is also provided with bearings *b b*, through which the shaft of the armature A extends. At each end of the armature-shaft is keyed a pinion *g*, engaging with corresponding gear-wheels G, secured to the driving-axle *a* in such a manner that this axle may either revolve or be revolved by the armature A when the car is in motion.

It will be seen that when the motor M is connected as just described its operation is not affected by the motion of the car-body upon its springs, as the center of the armature-shaft remains constantly at a fixed distance from the center of the driving-axle, regardless of any vibration or swaying motion of the car itself.

The secondary battery B is preferably divided into two sections and placed under the seats at either side of the car. As the battery required for the purpose of this invention is quite small in comparison with that usually employed for electric cars, it can be very readily accommodated in the manner shown, and its weight will just serve to properly ballast the car and give it the needed traction. Moreover, as the battery is charged by the motor itself, it will be evident that it need not be removed for this purpose, and if at any time the potential of the battery should fall below its average to such an extent that the motor is unable to supply the deficiency during the usual charging intervals, as hereinafter more fully explained, it can be readily brought up to the required standard or depth of charge by connecting it with the line-conductors during such times when the motor does not require the current, or when the car is standing still, as hereinafter described.

The switching devices, starting and stopping mechanism, and regulating apparatus, &c., are located in a compartment at the front of the car, as shown in Figs. 1 and 2, where they are within convenient reach of the motor-man and protected from the weather and other injury.

While the current-collectors, motor, batteries, and switching devices are preferably arranged as just described, it will be evident that they may be of any other construction and located in any other desirable manner, according to the requirements of different railways, without in any manner departing from the spirit of this invention. It will also be understood that when this invention is applied to a train of cars each car may be equipped with its own motor and secondary battery, or the motor and secondary battery may be carried by the motor-car, or any other disposition may be made. In either case it is preferred that the switching devices be under the control of the motor-man in the forward car, and proper communication can be maintained between the cars by means of suitable circuit-connections. (Not shown.)

Referring now to the diagram view Fig. III, which illustrates the general arrangement of circuits and switching devices employed, P represents the positive line-conductor and N the negative line-conductor. *p* and *n* are the contact-wheels or other current-collectors by means of which the line-current is conveyed to and from the electro-dynamic motor. From my previous application, Serial No. 189,631, before referred to, it will be understood that these current-collectors can be moved with respect to the conductors P and N, so that the car may be driven forward or backward, or its motion arrested, by simply moving the handle H in the motor-man's compartment in the proper direction; but for the present we will suppose that they are constantly in contact with the line-conductors so as to propel the car in a forward direction.

The motor M is preferably shunt-wound and its field-magnet provided with a number of independent coils *m*, which are taken to a suitable hand-switch H, by means of which any desired number of coils may be included and the strength of the field thereby increased or diminished; or, instead of employing separate coils, I may insert a variable resistance in the field-magnet circuit, as shown in Fig. V, or regulate its strength in any other desirable manner.

B B is the secondary or storage battery, the two sections of which are connected by means of the switch *b*, so that they may be connected up or charged and discharged in different ways, if desired.

S, Fig. III, is an automatic switching-lever, which is pivoted to some fixed part of the car, and is capable of motion in the direction of the length of said car. This lever is weighted at its lower end, so that it will hang perpendicular whatever be the inclination of the car, and its upper end is provided with a fork within which a movable pin or stop s' on a cross-bar s^2 normally rests. The cross-bar s^2 is of insulating material and unites the two switch-arms S^P and S^N, which are pivoted to a suitable switch board or support S^2, and which are respectively in connection with the positive and negative terminals of the motor M. The switch-arms S^P and S^N are respectively adapted to come in contact with the terminal plates 1^P 2^P 3^P and 1^N 2^N 3^N when the weighted lever or "pendulum-switch" S, whose motion is limited and steadied by springs $s^3 s^3$, changes its position with respect to the car when the latter is ascending or descending a grade, as hereinafter described.

E is an electro-magnet or double solenoid having two oppositely-wound coils, and whose armature or core *e* is provided with an insulated extension having two metallic strips e^P and e^N, adapted, when the core *e* is drawn upward by the spring e^2, to make contact between the terminal plates 22 23 and 20 21, respectively, as shown in dotted lines.

The operation of the devices just described is as follows: When the car is running on a practically-level portion of the track, the pendulum-switch S hangs perpendicularly with respect to the shelf or support S′, and the switch-arms S^P S^N are in contact with the terminal plates 2^P 2^N, respectively, as shown. The current will now flow from the positive line-conductor P through contact-wheel or collector p and conductor 4 to plate 2^P, thence through switch-arm S^P and conductor 5 to the positive terminal 6 of the motor M; then by way of the negative terminal 7 over conductor 8, switch-arm S^N, plate 2^N, conductor 9, and contact-wheel n to the negative line-conductor N. The motor M is now receiving current from the line-conductors through the regular supply-circuit, (indicated by the heavy lines,) and will continue doing so as long as the parts remain in this position. Now, when the car, which is supposed to be running in the direction of the arrow v, begins to ascend a grade the pendulum-switch S, by virtue of gravity, will take up such a position with respect to the shelf S′ that the switch-arms S^P S^N will be moved along the plates 2^P 2^N until they also make contacts with the plates 3^P 3^N, respectively. With the switch-arms in this position, the motor M will still receive its current from the line-conductors through the plates 2^P 2^N, but in addition will receive a further supply of current from the secondary battery B B, which we will suppose has received an initial charge to begin with. This second supply of current will flow from the + terminal of the secondary battery over conductors 10 and 11 to the plate 3^P, and from the − terminal of battery over conductors 13 and 12 to the plate 3^N, thus joining the main-line current flowing through the motor-circuit in the direction of the arrow-heads, and considerably augmenting the power developed by the motor. The battery-current continues to flow through the motor until the car again comes to a level, whereupon the switching devices return to their normal position.

A portion of the battery-current normally flows through the lower portion of the solenoid E, the two coils of which are preferably of equal resistance and oppositely wound by way of wires 14 and 15 and energizes it so as to attract the core e, as shown, against the upward pull of the spring e^2. An adjustable rheostat R, the object of which will hereinafter appear, is preferably placed in this circuit, and it will be seen that the force with which the core e is attracted is proportional to the potential or strength of current in the battery. The upper coil of the solenoid is similarly connected by wires 17 and 18 with the charging-conductors 16 and 19, that lead from the plates 1^P 1^N and terminate at 22 and 20, respectively. Now, when the car is running on a downgrade the switch-arms S^P S^N are automatically moved so as to break connection with the line-conductors P N and establish connection with the charging-conductors 16 and 19. The armature A of the motor is now revolved by the moving car and the motor thereby converted into a generator. The connection with the line-circuit is broken in the new position of the gravity-switch, and as the armature of the motor is geared to the axle of the vehicle it will be rapidly rotated, performing the functions of a generator. While the rotation of the armature is in the same direction as before, the current generated flows through the circuit in the opposite direction, as indicated by the feathered arrows. As the available energy of a car moving on a downgrade in excess of that required to keep it in motion is at first somewhat small, but increases rapidly as the car gains headway, two things are necessary to the proper and satisfactory operation of this system. First, some provision must be made whereby the connection between the secondary battery and the generator is not made until the latter is capable of developing a current whose strength is slightly in excess of that in the battery, in order to prevent the battery-current from operating the motor and causing it to propel the car downhill. To meet this requirement is one object of the double solenoid, which in this capacity fulfills the functions of a "potential switch." It will be seen that when the core e is attracted by the lower coil of the solenoid the connection between the terminals 20 21 and 22 23 is broken. Consequently the first portion of the generated current, instead of flowing into the secondary battery, is diverted from the charging-conductors 16 and 19 into the upper coil of the solenoid, and as soon as the potential of the generated current equals or exceeds that of the secondary battery it neutralizes the attractive force of the current in the lower coil of the solenoid to such an extent that the spring e^2 will draw up the core e and establish connection between the charging-conductors 16 19 and the battery-wires 10 13, by means of the bridge-pieces e^P and e^N. The current will now flow from the positive brush 6 over conductor 5, switch S^P, plate 1^P, conductor 16, bridge-piece e^P, conductor 10, through the cells of the secondary battery B B, and return to the negative brush 7 of the generator by way of conductor 13, bridge-piece e^N, conductor 19, plate 1^N, switch-arm S^N, and conductor 8.

While the accumulators are being charged, as just described, a portion of the current will continue to flow through the two coils of the solenoid E and neutralize their mutual attraction for the core e sufficiently to enable the spring e^2 to preserve the continuity of the charging-circuit. As the resistance of the circuit of the lower coil is, however, slightly in excess of that of the upper coil, owing to the rheostat R, it follows that as the charging proceeds and the counter E M F or resistance of the battery to the charging-current increases, an increased amount of current is diverted through the solenoid-coils, of which the larger portion flows through the upper coil in virtue of its lower resistance, and this difference of resistance is so adjusted that at such times when the battery has received a full charge, or when it has been charged to such an extent as may be desired for practical working, its resistance or opposition to the charging-current will have become so great that this current will energize the upper coil against the counter attraction of the lower coil and attract the core *e*, thus breaking the charging-circuit to the battery. It will thus be seen that the solenoid E does not only determine the time of admission of the charging-current to the battery by means of the "potential balance," before described, but also cuts out the battery at the proper time to prevent overcharging and places it in a position to again receive the charging-current when it has become partially depleted.

While I have described a particular form of secondary-battery cut-out, I do not wish to be construed as limiting myself thereto, inasmuch as any form of appliance or apparatus by which the charging-circuit through the said secondary battery is interrupted when the latter receives the desired charge may prove satisfactory.

When the car is descending a grade, as before stated, its falling energy rapidly increases, and under the usual conditions of working it is necessary to apply the brakes in order to prevent the speed of the car from becoming excessive. As it is intended in this system to make use of all the available energy of the car or train whenever it is not required by the car or train itself, whether in descending an incline or coming to a stop, some provision must be made for withdrawing this surplus energy without in any manner interfering with the proper working of the car or train itself. This I accomplish by means of the hand-switch H, (see Figs. III and VIII,) by manipulating which the strength of the field-magnets, and consequently their attraction or retarding effect upon the revolving armature, can be regulated at will. The field-magnet circuit is intended to derive its current from the line. The means for shifting the circuit-connections by reciprocating the collecting-wheels, and thereby changing the relative direction of the field-magnet and armature currents, have not been specifically shown. However, any form of commutating-switch may be adopted for this purpose; but I have deemed it preferable in practice to utilize one form, which will be made the subject-matter of a separate application. It will be understood herein that by the simple reversal of the collecting-wheels by the motor-man the relative direction of the current through the field-magnet and armature coils is reversed by that operation. This, then, is what is meant by "reversible." When the switch H is moved entirely clear of the terminals *h* of the field-magnet coils *m*, no current will be generated by the motor M, the motion of the armature is not retarded by the field-magnet pole-pieces, and the car may move perfectly free with the exception of such force as may be expended by it in rotating the armature. When the switch is moved into contact with one of the terminals, a current is caused to circulate in the corresponding field-coil, a current of small quantity goes into the charging-circuit, and the rotation of the armature is slightly retarded. With every additional contact of the switch the strength of field and the amount of current generated by the reversed motor are increased, and a corresponding increase takes place in the retardation of the armature, or, in other words, in the resistance to the forward motion of the car, until if all the field-coils are brought into the circuit this resistance will be increased to such an extent as to practically brake or stop the car, as hereinafter described.

On ordinary railways I prefer to place the switch H under the control of the motor-man, as shown, so that the strength of the field, and consequently the amount of retardation or braking force exerted by the field-magnets on downgrades or the power developed by motor on upgrades, may be varied by him as circumstances may require; but when this system is applied to railways on which comparatively few stops are to be made, or where constant uniformity of speed is a consideration, or when a railway is operated according to the "telpherage" system—that is to say, an electric railway in which the movement of the cars or trains are controlled from one or more fixed operating-stations—then and in such case the field-switch H is preferably connected with the pendulum-switch S in such a manner that the strength of field will be automatically varied, according as the car or train may happen to ascend or descend an inclined portion of the railway, so that the speed of the car or train will remain practically uniform whether the direct or secondary current, or both, be employed. An arrangement of this kind is shown in Fig. V, which also illustrates a modified form of the automatic switching apparatus. In this figure the strength of the field-magnets is regulated by introducing more or less resistance into the field-circuit instead of employing separate coils, though of course the latter plan may be used with this arrangement, if desired. The arm H is pivotally secured to the shaft of the pendulum-switch, and is adapted to make contact with a double series of terminal plates or segments arranged on either side of a central line and connected in the manner shown. When the car is running on a level, the arm H occupies the central position, as indicated, and the resistance in the field-circuit is at its greatest, as the motor will then not be required to develop its full power. As the car ascends a grade the arm H moves to the right and diminishes the resistance of the field-circuit to an extent proportionate to the inclination of the grade, thereby admitting a larger portion of current to the field-magnets and increasing the power of the motor, in which it is assisted by the current from the secondary battery, as before explained. When the car descends a grade, the arm H moves to the left and likewise increases the flow of current to the field-magnets, this time, however, for the purpose of utilizing the generating-power of the motor to its greatest extent and at the same time retarding the forward motion, so as to keep the speed of the car within proper limits.

It has already been stated that the stop or projection s' on the cross-bar s^2 is pivoted so that it can readily be thrown into or out of engagement with the forked end of the pendulum-switch S. This pin is shown clearly in detail in Fig. IX. When it is desired to slow down or stop the car, say, on a level track, the stop s' is lifted out of its fork, and the switch-arms S^P S^N moved to the terminal plates 1^P 1^N. This action will cut off the connection between the motor M and the track-conductors and establish the connection between it and the charging-conductors 16 and 19, as already specified. The momentum of the car or train can now be transformed into electrical energy delivered into the secondary battery by means of the switch H, as before described, which may be operated to slow down and stop the car or train within any desired space of time. Inasmuch, however, as the retarding influence of the field-magnet upon the revolving armature is greatest when the armature revolves fastest, and decreases rapidly as the speed of the car, and consequently that of the armature, diminishes, it will be necessary, when quick stoppages are desired, to make use of additional brake devices to fully stop the car or train after its speed has thus been brought under control. This may be accomplished in various ways; but I prefer to employ for this purpose the method set forth in another application, filed by me on November 4, 1885, Serial No. 181,808. When this method is employed, the cars are provided with electro-magnetic brake devices, preferably of the kind set forth in my said application, though any other good construction will answer, and a current from the secondary battery is admitted gradually to the said brake devices by means of a suitable circuit closing or transmitting apparatus under the control of the motor-man. This supplementary brake-circuit is shown diagrammatically in the present drawings, Fig. III, at X, leading from the main working-circuit W of the secondary battery. X' is the circuit-closing apparatus, and x x represent the electro-magnetic brake devices.

After the car has been stopped, as above described, and it is desired to start it again the switch-arms S^P S^N are moved from 1^P 1^N to the plates 2^P 2^N, where they are allowed to rest a moment while the motor begins to revolve, and then are temporarily moved into the position occupied by them in going up-hill—that is, bridging the space between the plates 2^P 3^P and 2^N 3^N, respectively. The current which has been generated and stored in the battery during the process of stopping the car is now again given out by the battery, in the manner already specified, to re-enforce the main-line current in overcoming the inertia of the car and in bringing it rapidly under full headway, upon arriving at which the stop s' may be again placed in the fork and the car allowed to continue its way. Thus it will be seen that the greater part of the energy taken from the car or train in stopping is again restored to it in starting, and in like manner the power given out by the car or train in descending an incline is stored up in the accumulating-battery and given back to the train when it is most required, viz: in ascending an incline. Practically, then, it will be apparent that, as on a round trip the total upgrades and downgrades and the total number of startings and stoppages counterbalance each other, the total amount of current that need be provided at the generating station or stations for operating the line will, allowing for losses in conversion and transformation, be but thirty or thirty-five per cent. more than that required to keep the cars or trains running on a level, as against an expenditure of, in many instances, several hundred per cent. on similar roads as at present operated, and the more numerous and steeper the grades the more economical will be the cost of operating by this system as compared with that of any other system now in use.

It may sometimes occur that the current in the accumulating-battery is drawn upon to a greater extent than it can be supplied by the motor during an ordinary run over the road, and some provision should therefore be made for replenishing the charge in the battery independently of the motor. Especially is this necessary when the secondary battery is employed to furnish electrical current for other purposes, as shown, for example, in Fig. III of the present drawings, in which the battery-current is also utilized for lighting the car by supplying current to the electric lamps l, located in the sub-circuit L, and for operating the brake devices x in the sub-circuit X, as before described. With this object in view I have provided a supplemental switch s, which can be operated to connect the secondary battery with the line-conductors at such times when the car is standing or the motor does not require the track-current. In the present instance the connection with the line-conductors is made by electrically connecting the terminal plates 2^P 3^P and 2^N 3^N, respectively, by means of the switch s, the switch-arms S^P S^N meanwhile occupying the insulated space between plates 1^N 2^N and 1^P 2^P, though any other suitable switching arrangement may be employed as well. It will be understood that at such times when the battery is connected with the line-conductors its potential is less than that of the line, so that it will readily receive the charge, and as soon as it has become properly charged it will be cut out by the solenoid E in the manner previously specified, upon which the switch s is to be restored to its normal position.

With all the cells of the secondary battery connected in multiple arc, as shown, the battery will give a large current with comparatively low electro-motive force, and will offer a correspondingly-low resistance to the charging-current. It may, however, be desirable to change this arrangement somewhat in practice to meet the various demands made upon the battery, so that while still being capable of receiving a charge at a comparatively-low electrical pressure, in order to utilize the smallest as well as the largest amount of current that is generated by the motor, it will at the same time be in a position to return this energy when it is wanted at a higher electrical pressure or at several different pressures when so required—as, for instance, a different pressure each for operating the brakes, for running the motor, and for supplying the lamps. It is obvious that this may be accomplished by arranging the battery-cells so that they may be charged and discharged in the desired manner, and making the various changes either manually or automatically by means of a suitable commutator-switch. I have not shown this feature in the present application, as such an arrangement of switching devices will form the subject of a separate application for Letters Patent.

Fig. IV illustrates on a larger scale a modification of the switch-board shown in the diagram view Fig. III, in which the terminal plates or segments are each subdivided into a number of smaller segments, which in turn are connected to a series of binding-posts, as shown. The object of this construction will be readily understood in connection with the foregoing description. The segments of group 3^N and 3^P are each connected to a portion of the secondary battery, in order that the increase of current flowing to the motor from the battery will be gradual and more nearly in proportion to that required by it in starting or in ascending any given grade. In the same manner a suitable resistance is interposed between each of the segments of group 2^N and 2^P, so that the resistance of the motor-circuit will be automatically varied according to the inclination of the pendulum-switch, in order that the amount of track-current flowing to the motor may be automatically regulated and adjusted to suit the varying demands occasioned by the changes in grade. The individual segments of the terminal plates 1^N and 1^P, respectively, may be connected together when the solenoid E is employed in the manner before described; but under certain circumstances they may be connected with portions or sections of the secondary battery in the same manner as the segments 3^N and 3^P, so that the section of battery that is first to discharge through 3^N and 3^P will be the first to receive a charge through 1^N and 1^P, and thereby substantially preserve an equal charge in all the sections of the secondary battery. I have not shown the battery-connections in the present drawings, as these may be varied to suit different requirements, and will be readily understood by any practical electrician.

Although I have been particular in describing automatic switching devices for changing the circuits and graduating the flow of current according to the varying inclinations of the roadway upon which the car or train is traveling, it will be clear that this may be done manually, if desired, by simply moving the switch-arms in the required direction by means of the projecting stud s', Fig. IV. On ordinary street-surface railways, where the stops are very frequent, this may be found more advisable; but on railways in which the stoppages occur less frequently, and especially on those in which the gradients are well defined, I prefer to operate the switching and regulating devices automatically, as already described, on account of the greater uniformity in the results gained and less attention required on the part of the motor-man. I do not, however, limit myself to the particular kind of automatic switching devices and circuit-connections already described, but may use other forms of switching apparatus—such, for example, as the types represented in Figs. V and VI. Of these Fig. V shows a modification of the pendulum-switch, in which the switch-arms S^N and S^P and the field-regulating switch H are combined with the pendulum and move about its pivot as a center.

The pendulum S is locked to an arbor secured to the arms S^N S^P during the normal operation of the switch H by means of the pivoted locking-pin h^2. When, however, it is desired to operate the switch H by hand, the pin h^2 is elevated, thereby allowing the pendulum to rock upon its arbor, and thus the switch H can, in this instance, be adjusted by hand without affecting the motor-connections.

Fig. VI illustrates a form of liquid-switch depending for its action upon the difference in the amount of liquid in the receiving-chambers at its extremities due to the inclination of the car. This switch apparatus is supported on a central pivot, and operates electrically in the same manner as the pendulum-switch in Fig. V. However, the other modifications shown in before-mentioned figures will not be further described, as all forms of these automatic switches are to be reserved for further applications, as will appear hereinafter, and are merely illustrated in connection with the form utilized in the diagrammatic view.

In Fig. III of the present drawings I have shown the motor provided with but a single pair of brushes, which are all that is necessary for running the motor forward or backward when the railway is operated as described in my application Serial No. 189,631, before referred to. I may, however, employ a double set of brushes, if desired, and change the direction of current flowing through the armature or field-magnets in any other desirable manner for converting the motor into a generator and for running forward or backward, or may use a special form of motor different from that described and specially adapted to the requirements of operating the car or train, as herein described.

The several forms of gravity-switch illustrated in Figs. III, V, VI, VII^A, and VII^B, the switch shown in Fig. IV, and the potential cut-out in Fig. III are not to be specifically claimed herein, but are reserved for future application, which will be filed subsequently.

What I claim is—

1. In an electric railway, the combination of line-conductors, a suitable generator for supplying current to said conductors, a traveling electric motor, an auxiliary generator, and an automatic switch controlled to correspond with the inclination of road-bed to connect and disconnect said auxiliary generator with the said motor, substantially as specified.

2. The method of operating an electrically-propelled vehicle or train, which consists in supplying motive-current from a line to an electric motor, said current being of sufficient strength to operate the vehicle on substantially-level portions of the line, converting the said motor into a generator when the said vehicle or train is on a downgrade or slowing down, storing the electrical energy so developed into secondary or storage batteries, and utilizing the energy thus stored for re-enforcing the line-current when an abnormal amount of current is required, substantially as specified.

3. The method of operating a vehicle or train, which consists in supplying the propelling electric motor with motive-current, re-enforcing said motive-current, when the vehicle is starting, with an additional supply of current from a generator located upon said vehicle or train, continuing said re-enforcement until the said vehicle or train has acquired the desired momentum, and cutting out the re-enforcing current, substantially as specified.

4. The method of operating an electrically-propelled vehicle or train, which consists in converting the propelling electric motor into a braking-generator adapted to be so operated by the momentum of the vehicle or train when slowing down or coming to a stop, storing the generated electrical energy in a secondary battery carried by said vehicle or train, and employing the energy thus stored, or a portion thereof, to assist or augment the propelling force in starting, and imparting the desired momentum to the vehicle or train by discharging such stored energy into the propelling-motor contemporaneously with the primary motive-current, and at substantially the same electro-motive force, substantially as specified.

5. The method of operating an electrically-propelled vehicle or train, which consists in driving the same on substantially level portions of the road-bed or line by a line-current, converting the said motor into a generator when the vehicle is on downgrades or slowing down, utilizing the mechanical energy so expended on downgrades or when slowing down for producing a generation of current, storing the current thus generated in a secondary battery, and utilizing such stored energy to operate electro-mechanical brakes located upon said vehicle or train, so as to completely arrest the motion of the latter, substantially as specified.

6. The method of storing the waste electrical energy of the electrically-propelled vehicle or train, which consists in supplying the propelling electric motor with current from a line, converting the said electric motor into a generator of electricity, operating the said generator by the momentum of the vehicle or train, disconnecting the motor from the line-supply, and connecting it with the circuit of a storage-battery, substantially as specified.

7. The method of storing up the waste energy of an electrically-propelled vehicle or train, which consists in supplying the propelling electric motor with current from a line, converting the driving electric motor into a generator of electricity on downgrades or when slowing down, operating the generator by the momentum of the vehicle or train, disconnecting the generator from its line-supply, connecting it with the circuit of a storage-battery, and varying the strength of the current so generated and its braking capacity by increasing the field-magnet strength, substantially as specified.

8. The combination, with an electric circuit, of a circuit-controlling lever pivoted to hang vertically, mounted upon a traveling vehicle and operated by and in accordance with the inclination of the line of way over which the vehicle travels, substantially as described.

9. The combination, with a dynamo-electric generator mounted upon a traveling vehicle, having a circuit-controlling mechanism included in the circuit of the field-magnet coils, of a pendulum-lever controlling said mechanism by and in accordance with the inclination of the line of way over which the vehicle travels, substantially as described.

10. The method of operating an electrically-propelled vehicle or train, which consists in propelling said vehicle or train normally by an electric motor supplied with current from a line, gradually cutting in a storage-battery carried by a vehicle into the charging-circuit in a degree proportional to the inclination of the road-bed on downgrades, charging said battery through the circuit thus gradually made, and conducting the stored energy into the propelling-motor when on upgrades or when starting, substantially as specified.

11. In an electric railway, the combination

of a line-circuit, a traveling vehicle or train, a propelling electric motor and a storage-battery carried upon said vehicle or train, and a switching device controlled and operated to correspond with the inclination of the gradients of the line of way, whereby the line and battery may be connected in multiple arc with the motor, substantially as specified.

12. In an electric railway, the combination of a line-circuit, a traveling vehicle or train, a propelling electric motor and a storage-battery carried upon said vehicle or train, a switch in the field-magnet circuit of the motor, means for gradually varying the current-strength in said circuit on downgrades or when slowing down, and a switch for cutting the motor out of the line-circuit and in circuit with a storage-battery on downgrades, substantially as specified.

13. In an electric railway, the combination of a line-circuit, a traveling vehicle or train, a propelling electric motor and storage-battery carried by said train, a gravity-switch operated to correspond with the gradients along the line, switch-contacts and circuit-connections with the line-supply conductors, motor and storage-battery, and a variable resistance in the field-magnet circuit of the motor, controlled by a switch, whereby the motor may be converted into a generator on downgrades for charging the battery and the battery and line currents both may be cut in on upgrades.

14. In an electric railway, the combination of a line-circuit, a traveling vehicle or train, a propelling electric motor and storage-battery carried by said train, a gravity-switch operated to correspond with the gradients along the line, switch-contacts and circuit-connections with the line-supply conductors, motor and storage-battery to connect the battery and line in multiple arc with the motor on upgrades and the battery and motor in circuit with each other on downgrades, a variable resistance in the field-magnet circuit of the motor operated by said gravity-switch, whereby the motor may be converted into a generator on downgrades, and a potential switch controlled by a branch of the battery-circuit to cut said battery in or out of circuit, according to the condition of its charge, substantially as specified.

15. In an electric railway, the combination of line-conductors, an electrically-propelled vehicle, a motor and storage-battery carried thereon, a switch for connecting either the motor or battery into the line-circuit, a potential switch in a branch of the battery-circuit to cut said battery in or out of circuit, according to the condition of its charge, suitable translating devices in another branch circuit from said battery, and a switch for controlling said translating devices, substantially as specified.

16. The combination, with a dynamo-electric generator mounted upon a traveling vehicle and having circuit-closing mechanism in its field-magnet circuit, of a weighted pivoted lever automatically controlling said field-magnet circuit and arranged to be operated by gravity, substantially as described.

This specification signed and witnessed this 17th day of June, A. D. 1886.

ELIAS E. RIES.

Witnesses:
LEOPOLD RIES,
ALBERT H. HENDERSON.