(No Model.) 4 Sheets—Sheet 1.

M. HUTIN & M. LEBLANC.

TRANSFORMER SYSTEM FOR ELECTRIC RAILWAYS.

No. 527,857. Patented Oct. 23, 1894.

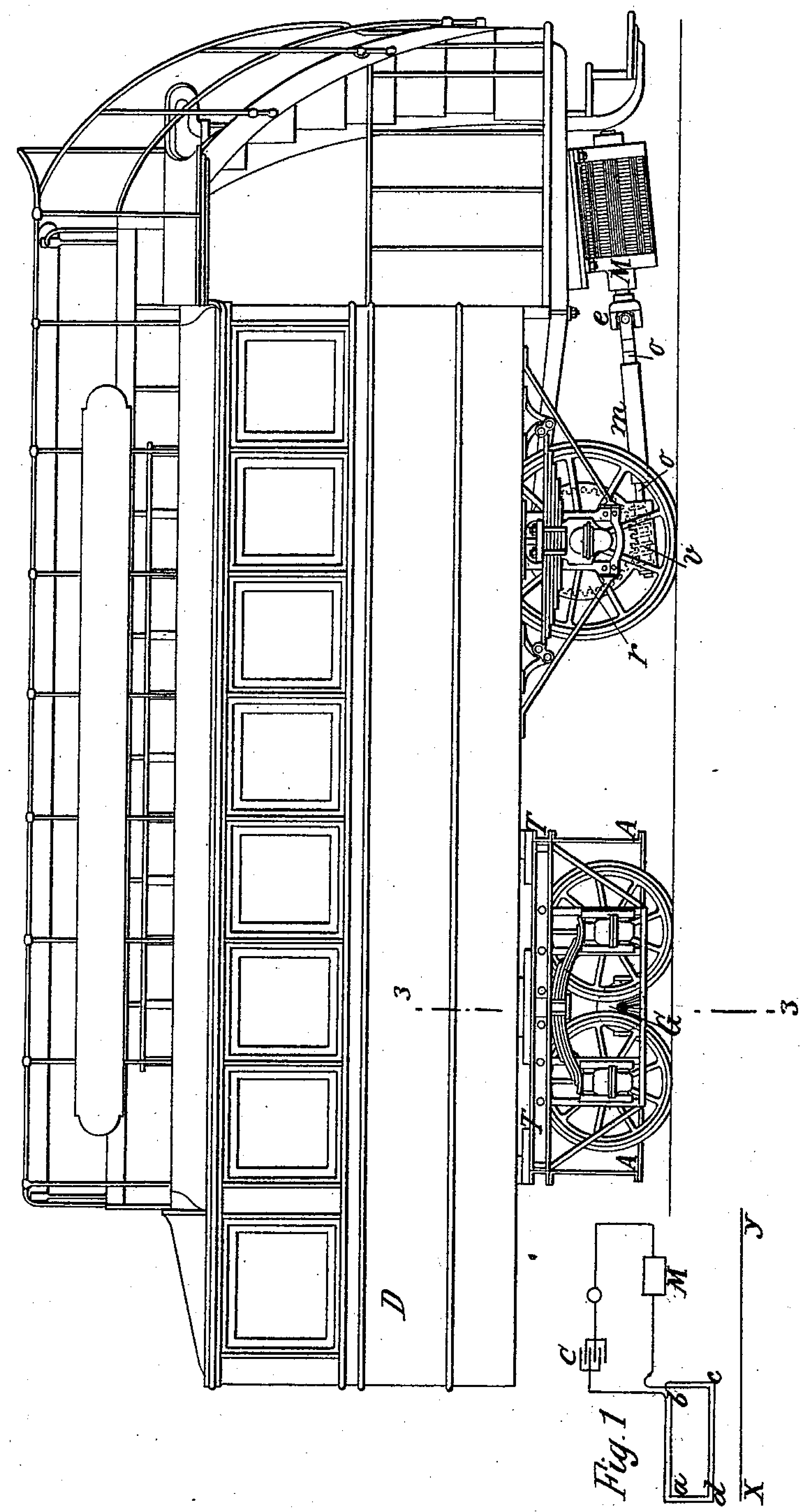

Fig. 2

Fig. 1

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(No Model.) 4 Sheets—Sheet 2.

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Fig. 3

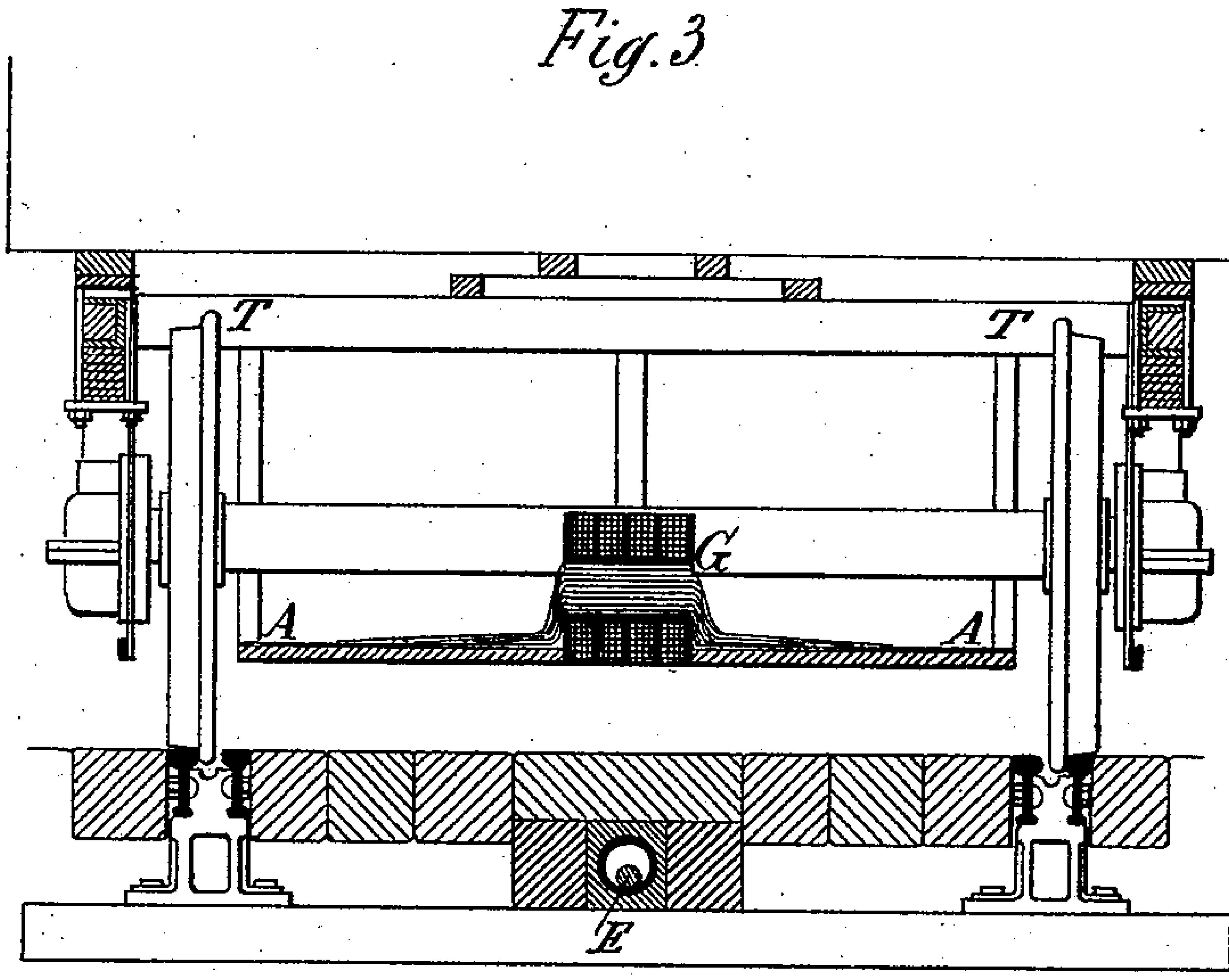

Fig. 4

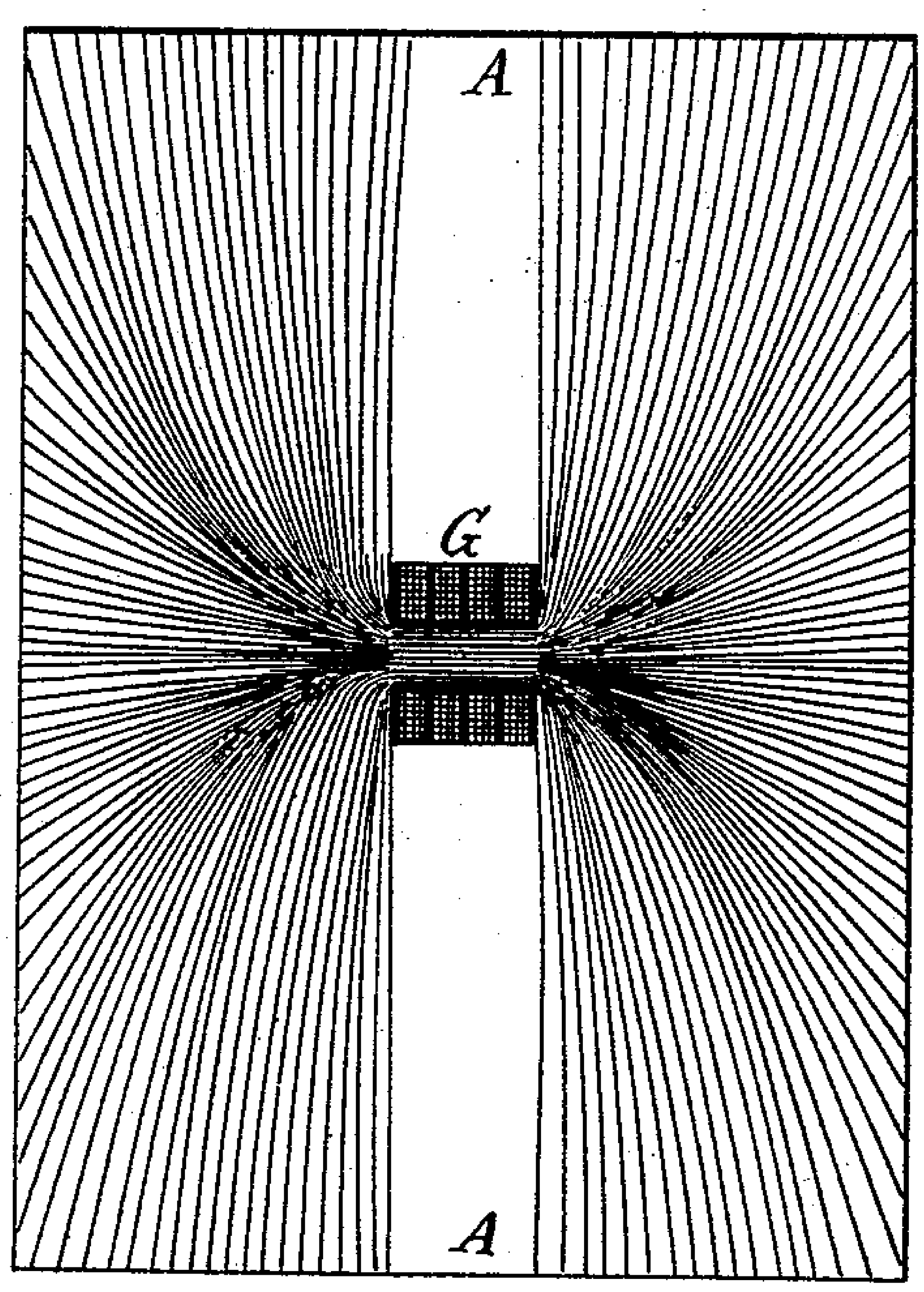

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Fig. 5.

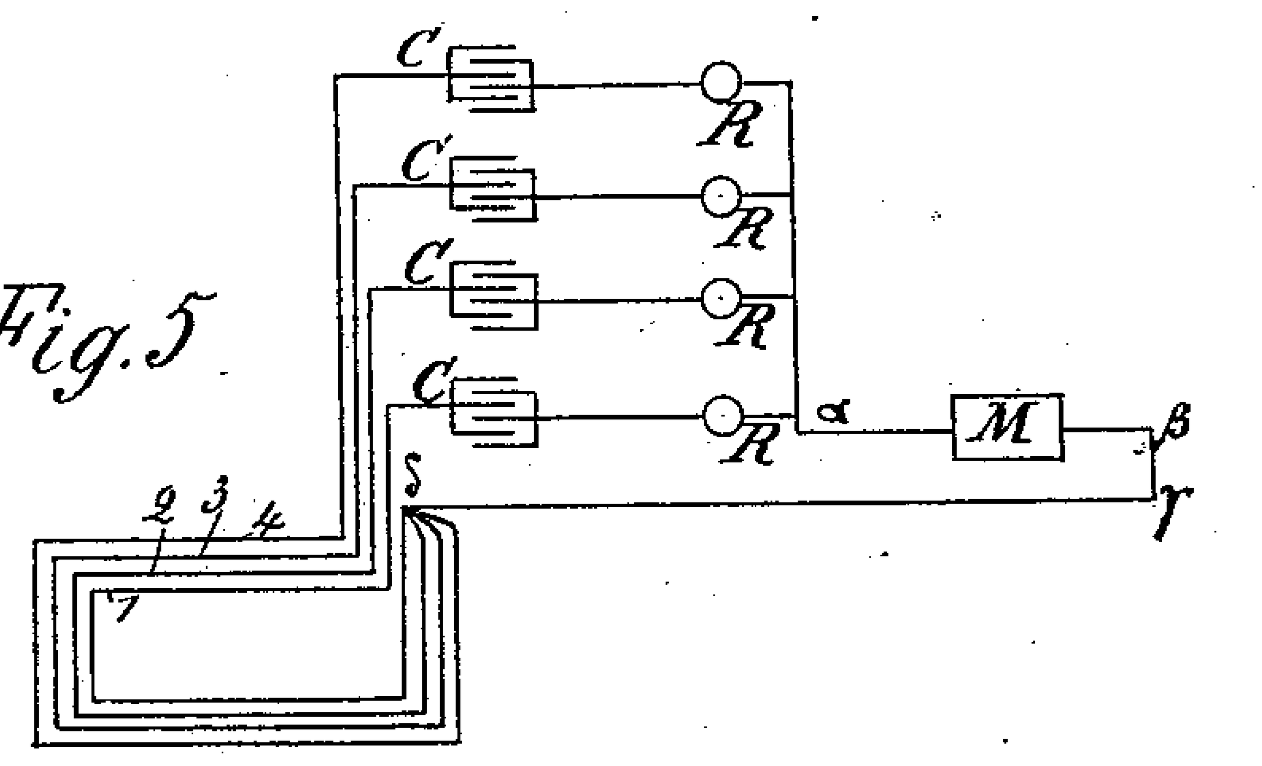


Fig. 6

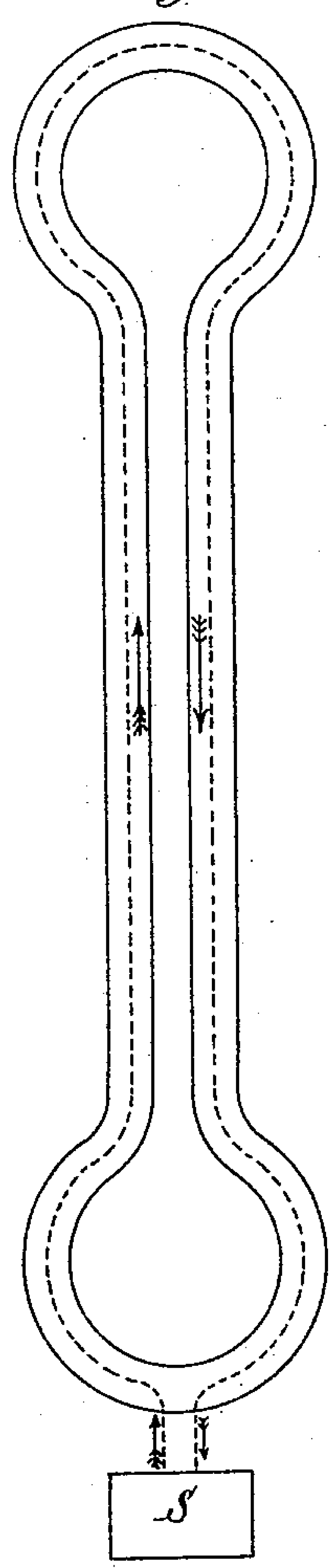
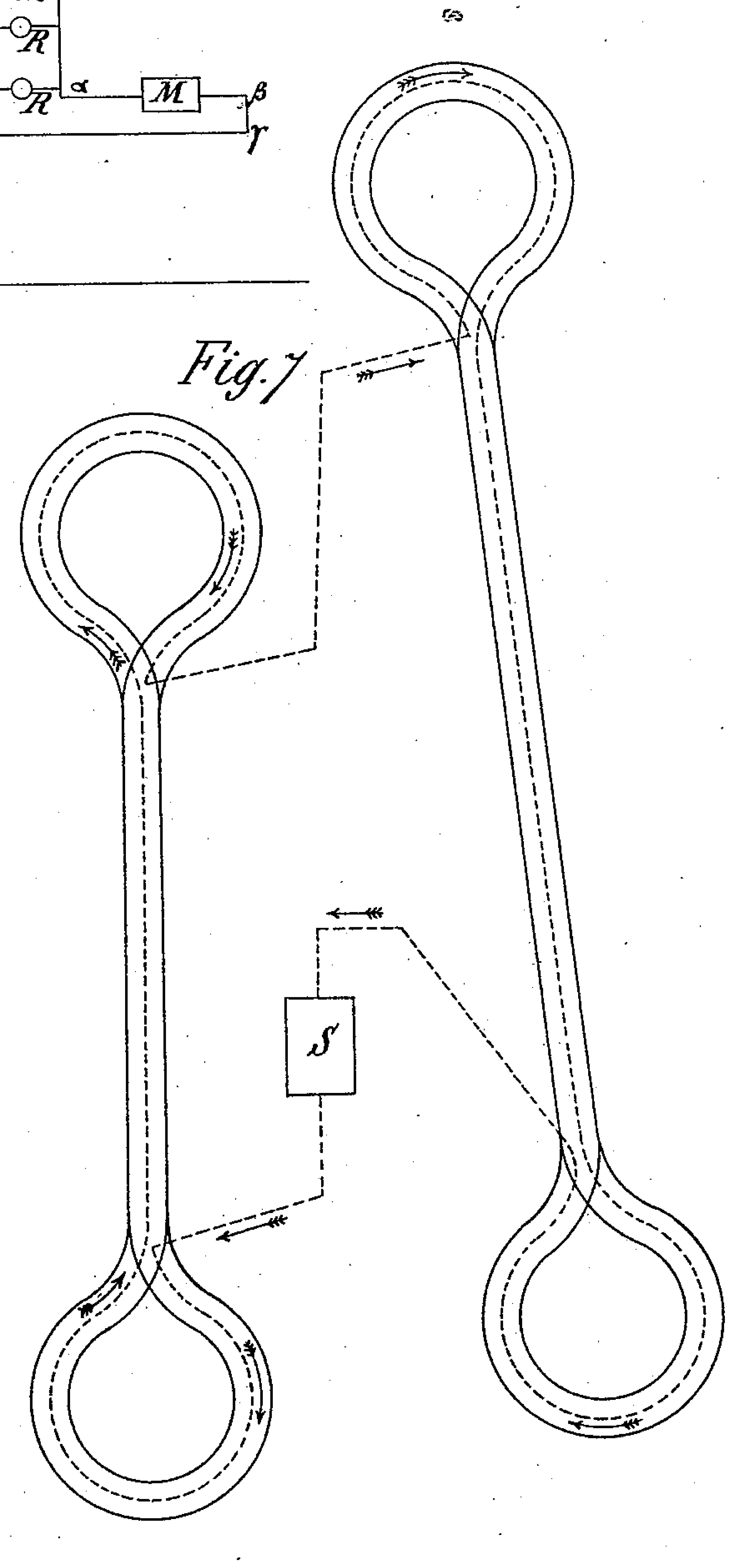


Fig. 7



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TRANSFORMER SYSTEM FOR ELECTRIC RAILWAYS.

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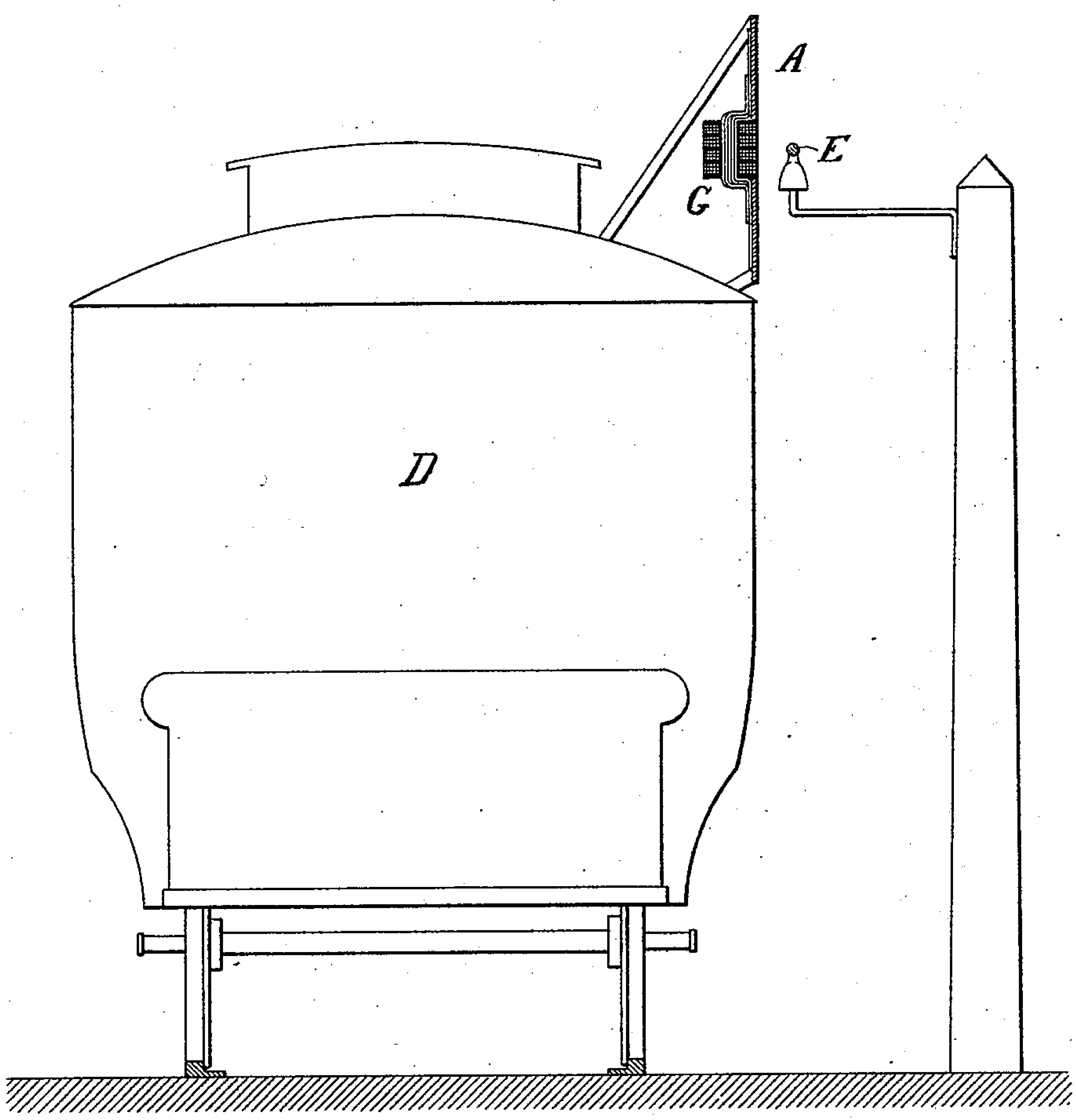
Fig. 8.



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UNITED STATES PATENT OFFICE.

MAURICE HUTIN AND MAURICE LEBLANC, OF PARIS, FRANCE, ASSIGNORS TO THE SOCIÉTÉ ANONYME POUR LA TRANSMISSION DE LA FORCE PAR L'ÉLECTRICITÉ, OF SAME PLACE.

TRANSFORMER SYSTEM FOR ELECTRIC RAILWAYS.

SPECIFICATION forming part of Letters Patent No. 527,857, dated October 23, 1894.

Application filed November 16, 1892. Serial No. 452,145. (No model.) Patented in France November 5, 1890, No. 209,323.

To all whom it may concern:

Be it known that we, MAURICE HUTIN and MAURICE LEBLANC, both citizens of the Republic of France, and both residents of Paris, France, have invented certain new and useful Improvements in Systems of Electric Traction for Vehicles, (which invention is patented in France, No. 209,323, dated November 5, 1890,) of which the following is a specification.

This invention relates to a method of and apparatus for electric traction of vehicles, and aims to provide certain improvements in this direction, which will be hereinafter fully set forth.

In the accompanying drawings which illustrate certain adaptations of our invention, Figure 1 is a diagrammatic view. Fig. 2 is a side elevation of a tramway car or other vehicle provided with our improvements. Fig. 3 is a fragmentary cross section thereof on an enlarged scale, showing the tramway in section, and cut on the line 3—3 in Fig. 2. Fig. 4 is a plan view of the secondary coil showing its bobbin in section. Fig. 5 is a diagrammatic view. Fig. 6 is a diagrammatic view of a double track tramway, showing the disposition of the electric conductor, and Fig. 7 is a diagrammatic view showing two single track tramways and the disposition of one conductor utilized for both. Fig. 8 is a vertical transverse section showing a modified arrangement.

The driving of railway vehicles by electric power should offer the greatest advantages as to facility and economy if only the energy supplied from a stationary plant could be transmitted directly to the vehicle from an electric conductor along the line. It is, however, very difficult to establish a constant communication between the vehicle and the electric conductor under proper conditions. In the case of high speed railways the difficulty arises principally from the great velocity with which the movable contact has to traverse the conductor; while in the case of tramways the use of an overhead wire presents serious disadvantages in public streets, and the use of a subterranean wire carried in a conduit or tunnel beneath the pavement having a slot for the passage of the movable contact, is unduly expensive; and finally, the use of the rails as conductors causes much leakage, or if the circuit is divided into a great number of sections in order to diminish this loss, excessive complication is involved. It has been proposed to overcome these difficulties by employing alternating currents for transmitting energy over the line in connection with coils carried by the moving vehicles the motors of which are energized by the alternating secondary currents generated in these coils; but heretofore this plan has not been practically available because of the extreme loss resulting from the wide separation of the primary conductor and the said coils, in connection with the necessity of transmitting the lines of force through the air, the magnetic conductivity of which is about two thousand five hundred times inferior to that of iron, which latter as is well known, is ordinarily employed in transformers for converting the energy from a primary to a secondary circuit.

According to our invention we propose to employ alternating currents for transmitting the energy, but in order to overcome the difficulties heretofore encountered, we have devised the system hereinafter described.

Referring to Fig. 1 of the annexed drawings, let X Y designate a line wire or conductor over which passes an alternating current, while *a b c d* is a coil arranged with the plane of its spirals parallel with the line wire, and connected in circuit with an electric motor M, which for example we will assume to be adapted for utilizing alternating currents.

The principles involved in the operation of such a system will be as follows: First, by reason of the inductive effect of the primary alternating current, there will be generated in the coil included in the secondary circuit (which coil will hereinafter be termed "secondary coil") an electro-motive force proportionate to the volume of the alternating current and to its frequency. Consequently, however low may be the mutual coefficient of the line, and of the secondary coil, and however small may be the volume of the alternating current upon the line, any desired electromotive force may be developed in the secondary coil by sufficiently increasing the frequency of alternation of the primary current; second, but while the electro-motive force developed in the secondary coil increases with the frequency, the apparent resistance of the coil will increase at the same time and will become sensibly proportional thereto. Hence it results that under these conditions the amount of energy transmitted to the secondary does not sensibly increase with the increase in the frequency of the alternating current thrown over the line. This result would no longer follow if the coefficient of apparent self-induction of the secondary coil were suppressed by introducing into its circuit condenser C (Fig. 1) of suitable capacity, or any other suitable means for suppressing or greatly reducing the apparent self-induction of the coil. In this case the apparent resistance of the coil would be always equal to its real resistance and independent of the frequency of alternation, and the energy transmitted to the coil would be proportional to the square of the frequency of the current. Consequently, however low may be the coefficient of mutual induction of the line and the secondary coil, and however small may be the volume of the alternating current upon the line, whatever amount of energy is desired may be rendered available in the secondary circuit on condition of employing an alternating current the frequency of which shall be sufficiently great, and of nullifying the coefficient of self-induction of the secondary coil by introducing into its circuit a condenser of suitable capacity, or any other apparatus which will serve the same purpose. As such other apparatus constituting equivalents for the condenser, we will name, first, any voltameter in which the capacity of polarization is utilized, and which is introduced into the circuit wherein the self-induction is to be suppressed; second, any thermo-electric battery which is introduced into the circuit without providing any means for heating or cooling its joints; Third, the apparatus of our invention which we call a transformer of alternating currents into continuous currents, and which apparatus is fully shown and described in our British Patent No. 17,826 of 1892.

From the foregoing it will be seen that for transmitting the required energy to the vehicle, it will be necessary to lay in the ground parallel with the rails, an electric conductor in the same manner as the conductors for lighting purposes, that is, by insulating it completely and inclosing it for example in a conduit of earthenware. The vehicle will be provided with a secondary coil, the convolutions of which have their planes parallel with the electric conductor, and with a condenser or one of the above mentioned equivalents therefor, and with a motor which will be fed from the alternating currents generated in said coil, and which will be connected to drive the wheels of the vehicle.

For determining the capacity of the condenser we employ the following formula:

$$C=\frac{T^2}{4\pi^2 h},$$

in which T represents the period of the current employed and h the coefficient of self-induction of the circuit the effect of which is to be neutralized.

Having thus indicated the principle of our invention, we will now proceed to describe our system with reference to the accompanying drawings.

The tramcar shown in Figs. 2 and 3 has its front portion supported on a truck T resting on two pairs of wheels, while its rear portion is supported on the driving axle carrying a single pair of driving wheels. The truck T carries the secondary coil G, which receives the induction of the line. The secondary currents generated in this coil serve to feed an alternating current motor M supported beneath the car, and which drives the rear axle through the medium of a worm v and a worm-wheel r, or by any other system of gearing, rotation being communicated from the motor to the worm through a shaft o which is connected to the motor through a universal joint e and is made of two expansible parts longitudinally connected by means of a sleeve m.

The line conductor E shown in Fig. 3 should be constructed of a single copper cable laid in an earthenware conduit which is sunk in a mass of bitumen laid in the pavement.

In order not to be obliged to provide alternating currents of too great frequency, we have provided the following means for making the mutual induction coefficient of the line and secondary coil as great as possible. Beneath the truck T is suspended a board or platform A of wood or other insulating material, the same being mounted horizontally as near the surface of the ground as is practicable. This board occupies the whole available space between the wheels of the truck, and the secondary coil, which is here shown as an elongated bobbin G, is placed in the center of said board. A bundle of iron wires has its middle portion passed through the axis of the coil, while its protruding end portions are spread or radiated outwardly from the opposite ends of the coil on the board in such manner that the board is entirely covered by the radiating or diverging wires, with the exception of the middle portion of the board, which is left uncovered as shown in Fig. 4. By means of this construction the entire magnetic flow generated by the line crossing the board is received by the bundle of iron wires and conducted through the coil. The opposite terminals of the coil are connected by two flexible conductors with a condenser or other equivalent apparatus as specified, the same being situated along with the apparatus for governing the car, in a cabin D at the front of the car, where the motorman stands. From this apparatus the current goes to the motor.

For regulating the volume of current generated in the circuit of the car according to the work that is to be supplied at each moment, it would not be advisable to employ additional resistances which consume energy in mere waste. It is better to divide the convolutions of the secondary coil into several separate circuits, marked 1, 2, 3 and 4 in Fig. 5, each of these circuits being provided with its own condenser C, or with the equivalent apparatus specified. These different circuits unite in a common return wire $\alpha\beta\gamma\varsigma$ their other extremities being also united together, and in each of these is arranged a circuit-breaker R with graduated resistances. The motor M is introduced in the common return wire. According to the work to be done a greater or less number of the separate circuits will be closed to the motor.

The electric conductor E is situated at the middle of the track. Of course it ought not to include more than one conductor. On a double-track tramway, the natural course will be to carry the current along one track and return it along the other, as is shown in Fig. 6; but when the road has a single track, the best course is to utilize the same circuit for operating also another road, in the manner indicated in Fig. 7. If this is not possible, then the current must be conducted back through a special conductor passing far enough from the first, so that its inductive effect upon the cars is practically null.

In the case when our transformer of alternating currents into continuous currents is substituted for the condenser, the alternating current motor for driving the car may be replaced by a continuous current motor introduced in the secondary circuit of this transformer.

At first sight it might appear that the induction from the electric conductor being felt equally in the rails and in all the conductive bodies situated in proximity to the track, the useless currents thus produced might cause a great consumption of energy and make the effective utilization of power of this system very low. It will be sufficient to remark that we cannot take any considerable amount of energy from the line by means of our secondary coil unless we nullify the effects of self-induction in this coil by some special means. All the conducting bodies situated in proximity to the track not being provided with any special arrangement of this character, it results that the quantity of energy that they will absorb is inconsequential.

It is not necessary to employ a subterranean conductor situated at the middle of the track, as we may equally well employ an aerial wire mounted on telegraph poles placed along the track, on condition of arranging the secondary coil on the roof of the car. This is shown in Fig. 8.

It is evident that all that we have said relatively to the application of our invention to tramways, applies equally well to its application to railway trains.

It will be observed that in our system the rails have no other purpose but to confine the vehicle to a fixed path and to facilitate its travel.

Our system may be applied to any vehicles whatever in which the conductor or motorman is stationed at the front for controlling the vehicle.

We are aware that it has been proposed to drive electric tramcars by extending an insulated line wire either beneath the track or through the air above or at one side of the path of the car, causing alternating currents to traverse this wire, and providing the car with a secondary circuit including a coil serving the purpose of the secondary coil of a transformer, this coil being extended into close proximity with the line wire so as to be affected inductively therefrom, and the secondary circuit also including a motor to be driven from the alternating currents induced in the secondary coil for the purpose of propelling the car. In any such system the portion of the line wire in inductive proximity to the secondary coil corresponds to the primary coil of a transformer, while the portion of said secondary coil receiving the inductive effect of the line wire corresponds to the secondary coil of a transformer, but with this difference over transformers as universally constructed that in the latter a laminated iron core is provided constituting a closed magnetic circuit for receiving the magnetic lines of force generated by the primary and conducting them with the least loss by magnetic resistance to the secondary, while in the system referred to, since the secondary is continually shifting its position by the forward movement of the car, no such iron core can be employed, the only medium through which the inductive force can be transmitted being the air. It follows that inasmuch as iron has a magnetic permeability at least two thousand five hundred times greater than that of air, the efficiency of the traveling transformer referred to must be so excessively low as to become wholly inoperative to generate the power required for driving the tramcar, while at the same time the amount of energy consumed by wasteful induction in the track rails and other metallic bodies within inductive proximity to the line wire, would be considerable. Our invention overcomes these inherent and fatal defects by substituting on the line for an ordinary alternating current, an alternating current of high frequency, or one wherein the frequency is from fifteen to thirty times greater than the alternating currents ordinarily employed, say for example from one thousand to two thousand alternations per second; by which increase in frequency we overcome the difficulty due to the want of magnetic permeability in the intervening medium, air, between the primary and secondary; and then in order to render this advantage available, we introduce in the circuit of the secondary coil any suitable and known means for overcoming the self-induction thereof such as those specified. By the elevation of the frequency of alternation, the utmost effect of self-induction is manifested in the rails and other conducting parts in the neighborhood of the car, so that the loss by idle induction in those parts which are unprovided with any means for overcoming their self-induction is decreased in proportion as the effective utilization of energy in the secondary circuit on the car becomes augmented.

We claim as our invention the following-defined novel features, substantially as hereinbefore specified, namely:

1. The improvement in the art of electric transmission of power from a primary circuit or line to a secondary circuit by electric induction, whereby the intermediation of a closed magnetic circuit between the primary and secondary is dispensed with, the same consisting in generating in the primary circuit an alternating current of high frequency, and suppressing the self-induction of the secondary coil which is within inductive proximity to said primary, by means substantially as specified.

2. The improved means for the electric transmission of power from a primary circuit or line to a secondary circuit by electric induction, whereby the necessity of a closed magnetic circuit to carry the magnetic lines between the primary and secondary is dispensed with, consisting in the combination with a primary circuit or line carrying alternating currents of high frequency, of a secondary circuit including a secondary coil, a means for suppressing the self-induction of said coil, and a motor.

3. The improved system of electric traction, consisting in the combination with the vehicle to be driven of a stationary primary circuit extending longitudinally of its travel, and carrying alternating currents of high frequency, and a secondary circuit carried on said vehicle and including a secondary coil, a means for suppressing the self-induction of said coil, and a motor.

4. The improved system of electric traction consisting in the combination of the vehicle to be driven, a stationary primary circuit extending longitudinally of its travel and carrying alternating currents of high frequency, and a secondary circuit carried on said vehicle and including a secondary coil within inductive proximity to said primary circuit, a means for suppressing the self-induction of said coil, and a motor, and a laminated iron core for said secondary coil extended beyond the latter into closer inductive proximity to said stationary primary circuit.

5. In a system of electric traction, the combination of a stationary primary circuit for carrying alternating currents of high frequency, with a vehicle for traveling in the direction of said primary circuit, a secondary circuit carried on said vehicle and including a secondary coil G, and means for suppressing the self-induction of said coil, and a motor, a board A hung beneath said vehicle, and a bundle of wires passing through said coil and projecting beyond the ends thereof with their projecting portions extended on said board, substantially as and for the purposes specified.

6. In a system of electric traction, the combination of a stationary primary circuit for carrying alternating currents of high frequency, with a vehicle for traveling in the direction of said primary circuit, a secondary circuit carried on said vehicle including a secondary coil receiving the induction of said primary circuit, a condenser for suppressing the self-induction of said coil, and a motor to be driven by the currents induced in said coil, substantially as specified.

In witness whereof we have hereunto signed our names in the presence of two subscribing witnesses.

MAURICE HUTIN.
MAURICE LEBLANC.

Witnesses:
JULES ARMENGAUD, Jeune,
ROBT. M. HOOPER.