No. 714,196. Patented Nov. 25, 1902.

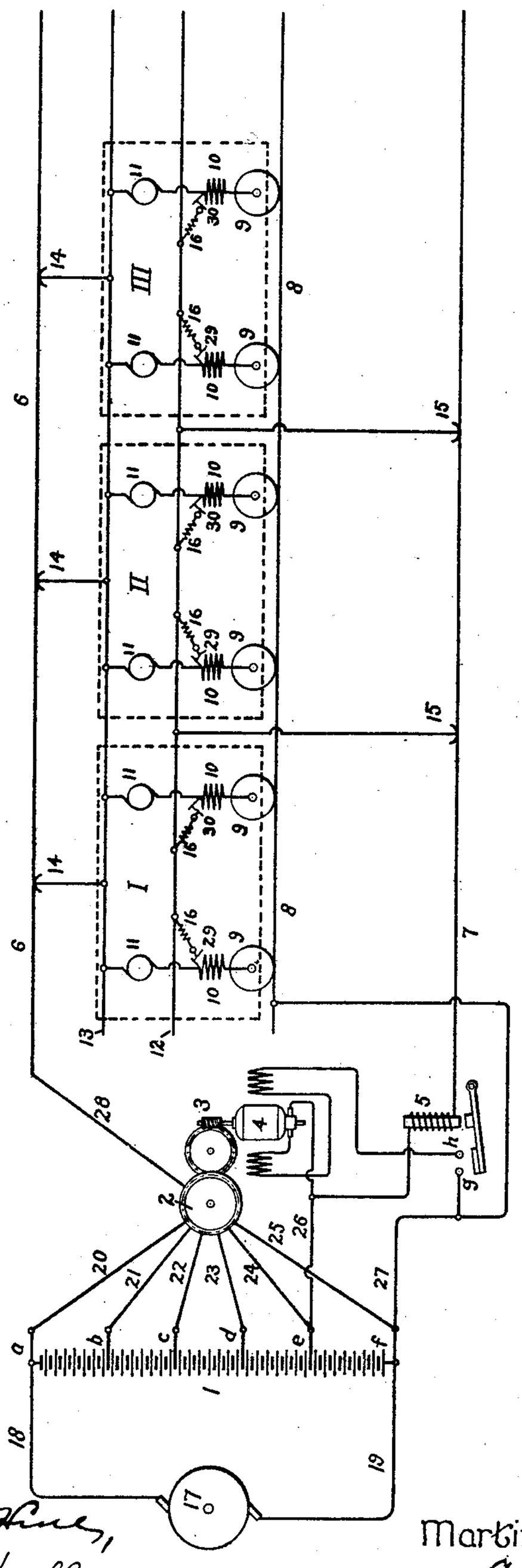
M. T. A. KUBIERSCHKY.

REGENERATIVE SYSTEM.

(Application filed Oct. 18, 1901.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.



Witnesses.
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No. 714,196. Patented Nov. 25, 1902.

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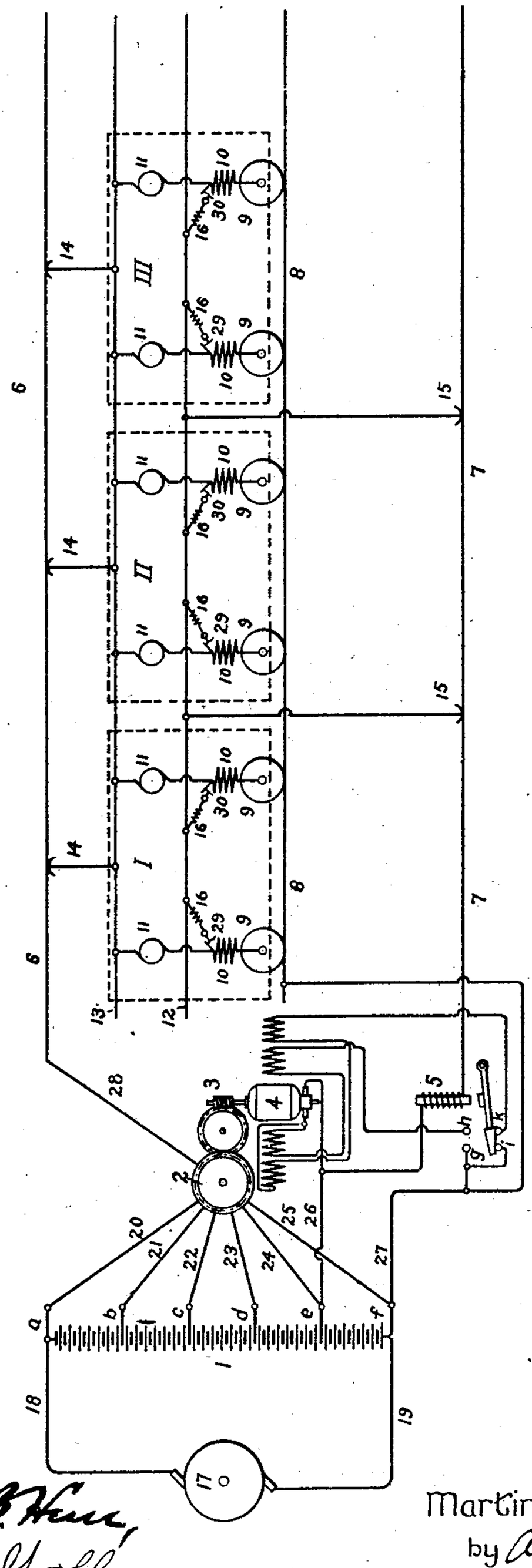
REGENERATIVE SYSTEM.

(Application filed Oct. 18, 1901.)

(No Model.) 4 Sheets—Sheet 2.

Fig. 2.



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REGENERATIVE SYSTEM.

(Application filed Oct. 18, 1901.)

(No Model.) 4 Sheets—Sheet 3.

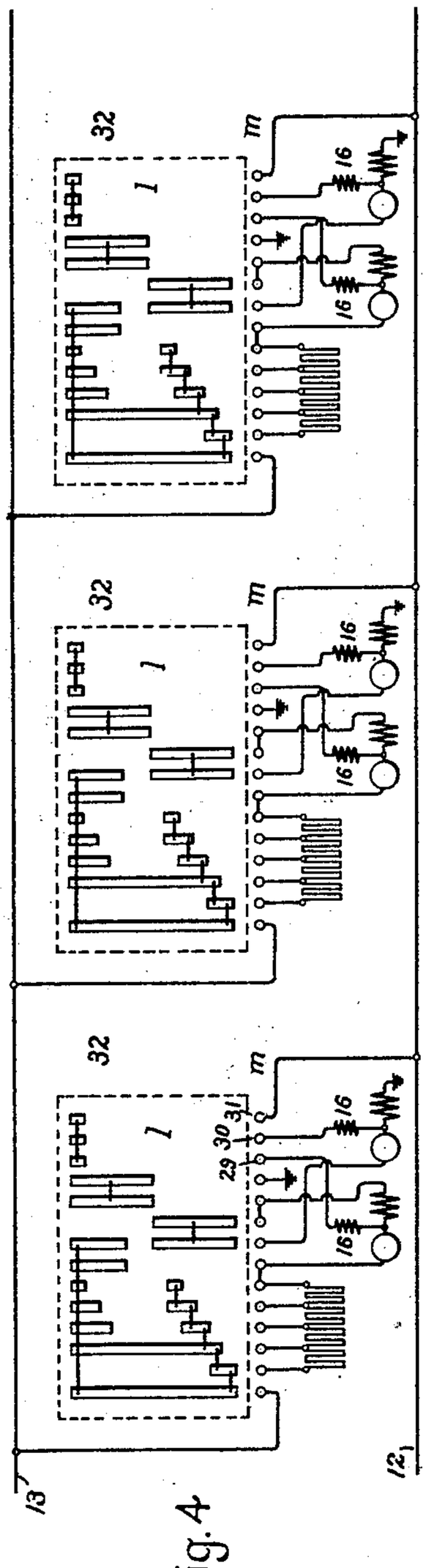

Fig. 4.

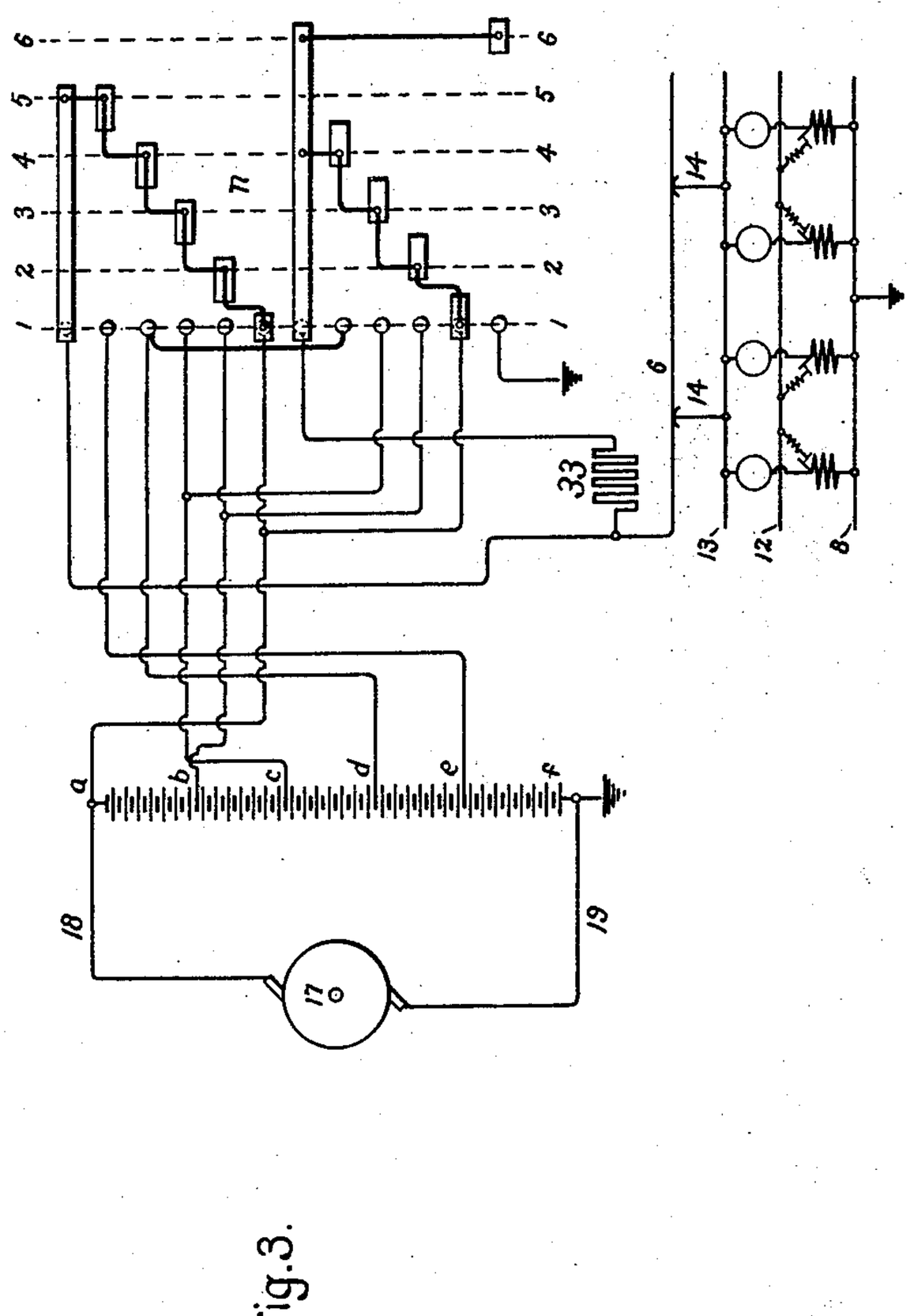

Fig. 3.

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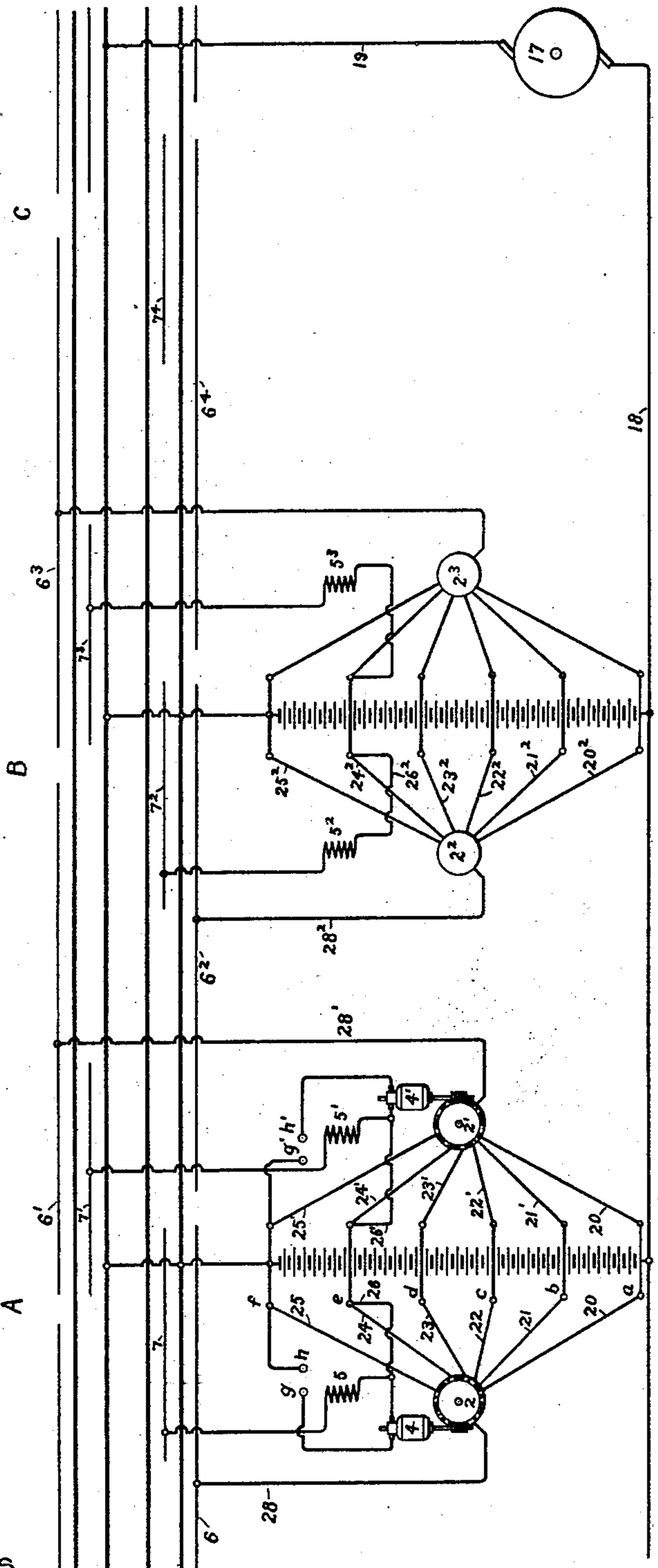
REGENERATIVE SYSTEM.

(Application filed Oct. 18, 1901.)

(No Model.) 4 Sheets—Sheet 4.

Fig. 5.



Witnesses.

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UNITED STATES PATENT OFFICE.

MARTIN T. A. KUBIERSCHKY, OF BERLIN, GERMANY.

REGENERATIVE SYSTEM.

SPECIFICATION forming part of Letters Patent No. 714,196, dated November 25, 1902.

Application filed October 18, 1901. Serial No. 79,139. (No model.)

To all whom it may concern:

Be it known that I, MARTIN T. A. KUBIERSCHKY, a subject of the Emperor of Germany, residing at Berlin, Germany, have invented certain new and useful Improvements in Regenerative Systems, of which the following is a specification.

My invention relates to a system of control especially adapted for restoring energy in the braking of electrically-actuated bodies, and has for its main object to so organize such a system that it may be utilized in the operation of the cars of an electric-railway system without requiring any auxiliary apparatus on the cars themselves.

When bodies having considerable mass are regularly and continuously so operated that any are alternately driven at a high speed and are then suddenly braked, as is the case in hauling plants, elevators, roller-train, and reversing rollers in roller-mills, and, above all, in railways, then the required output of power for such an operation is no longer equal to the product of friction and distance; but the actual consumption of energy is considerably higher and other conditions being equal increases with the speed at which the body to be driven must traverse a certain distance.

The kinetic energy which is stored in the moving body is uselessly destroyed in braking by means of ordinary brakes. The value of the energy wasted, so to speak, in this manner can be easily determined by calculation, and in many cases it is more considerable than is generally supposed. Thus, for example, a railway-train which is to run at an average speed of thirty kilometers per hour between stations which are separated by a distance of six hundred meters consumes, generally speaking, more than six times the amount of energy which is theoretically required to drive it over the same course at a moderate speed. Five-sixths of the entire energy supplied is thus uselessly wasted in such a case. If we can save of these five-sixths of the entire input but the half, a saving of about forty per cent. of the total consumption of power will be obtained. Besides this the capacity of the power-station can be correspondingly reduced, thus also decreasing the cost of the plant. Such a restoration of energy has been heretofore attempted and was realized by the system described in German Patent No. 104,016; but in the system disclosed in this patent it was necessary that the vehicle should carry some sort of a translating device constituting a subdivided source of electromotive force (as shown in the patent above referred to, the translating device consisted of a storage battery) for receiving the energy-current generated in braking.

The system which I have now devised permits of the location of the translating devices through which the restoration of energy is obtained along the line of the railway instead of on the vehicle.

My invention will be better understood from the following description, taken in connection with the accompanying drawings, while its scope will be pointed out in the appended claims.

Referring to the drawings, which illustrate an embodiment of my invention, Figure 1 is a diagrammatic representation of a train system in which the motors are arranged to restore energy to a stationary accumulator as the train is being brought to rest. Fig. 2 is a diagram of a modified system. Fig. 3 shows an arrangement of contacts which may be used on the controlling-switch which controls the connection between the accumulator and the propelling-motors in the systems of Fig. 1 and Fig. 2. Fig. 4 illustrates in development one arrangement of controller-contacts which may be used on each of the cars of the train shown in Figs. 1 and 2, and Fig. 5 is a diagram illustrating a double-track road provided with trolley-conductors arranged according to my invention and making use of a single set of accumulator-cells at the station for trains running in both directions.

Referring to Fig. 1, 17 indicates the generating source at the main generating-station which supplies the current for the railway system. It is connected by lines 18 and 19 with a storage battery 1, which is set up in or near a station. From the battery line 27 leads to the return-conductor, (in most cases, therefore, to the rails,) while lines 20, 21, 22, 23, 24, and 25 lead to a controlling-switch 2, the purpose and operation of which will be explained farther on. From the switch device 2 line 28 runs to the trolley-conductor 6

of the road. The several cars of the train are provided with the usual contact-shoes 14, arranged to engage the trolley-conductor. These shoes are connected to a line 13, which runs through the train and from which connections are made to the several controllers through which the supply of current to the car-motors is regulated. The return-circuit is through the car-wheels 9 and the return-conductor 8, (the rails.)

I II III indicate in outline the three cars of a train, each car being provided with two propelling-motors, the field and the armature windings of which are indicated at 10 and 11, respectively. The train may be provided with any suitable system for controlling the connections of the motors on the several cars; but since the control system constitutes no part of my invention I have not deemed it necessary to illustrate any such system in this case.

Preferably the motors when in operation will be controlled by the series-parallel method, and in Fig. 4 of the drawings I have illustrated an arrangement of contacts which may be used for making the series-parallel connection of the motors on the several cars.

If the controllers are of the cylindrical type, as indicated in development in Fig. 4, they may be simultaneously operated by any of the well-known train systems which are adapted for the operation of controllers of this type; but it will of course be understood that my invention does not depend on the character of the train system employed and may be utilized as well on a single car provided with propelling-motors as on a plurality of such cars connected to form a train.

As illustrated in Fig. 4, the motor-controller on each car is provided at one position with additional contacts arranged to make connections between the motor-circuits and a train-conductor 12, through small resistances 16, as illustrated in Figs. 1 and 2. The position in which these contacts are operative is the braking position of the controller, and in the particular arrangement of controller-contacts which I have illustrated in this case this is the full-multiple position; but evidently contacts arranged to make the braking connections may be placed at any desired position on the controlling-cylinder or they may, if desired, be placed on a separate cylinder by themselves.

The arrangement illustrated in Figs. 1 and 2 of the drawings contemplates the employment of two motors on each of the motor-cars, and in these figures the motors are shown connected in circuit as they would be for running at full speed—that is to say, they are all connected in multiple between the trolley-line 6 and the ground-conductor 8. The motors may of course be always maintained in the multiple connection; but in general it is preferable to make use of the series-parallel method of control.

The connection between the motor-circuits and the train-line 12 through the resistances 16 is supposed to be closed only when the motors are connected, as shown—that is, in full multiple between the trolley-conductor and ground. The resistances 16 are small and are preferably adjustable. They are used to compensate for differences in the resistances of the field-windings of the different motors, as will be hereinafter more fully explained. The line 12 is permanently in connection with the frictional contact-shoes 15, which are freely suspended when the train is run normally. In the vicinity of the station, however, and at the braking distance therefrom an auxiliary trolley-conductor 7 begins, (see Fig. 5,) onto which the contact-shoes 15 run as the train approaches the station. At the moment the shoes make contact the section *e f* of the battery 1 supplies current (see Figs. 1 and 2) through line 26, the actuating winding of an electrically-operated switch 5, line 7, contact-shoes 15, train-line 12, and the connections through resistances 16 to all of the motor field-windings 10 in multiple, the return-circuit being from conductor 8 through line 27 to the terminal *f*. As soon as this connection is made the tension at the armature-terminals of the car-motors becomes substantially independent of the current flowing therethrough—that is, the motors are separately excited. At the same time the above-mentioned electrically-actuated switch 5 effects the closing of a circuit for an auxiliary motor 4 at the contacts *g h*, so that this motor is supplied with current from the section of the battery *e f* through lines 26 and 27. The auxiliary motor 4 is connected through worm-gearing 3 with the controlling-switch 2, so that this switch begins to rotate as soon as the motor-circuit is closed. It is the function of the controlling-switch to gradually reduce the electromotive force impressed from the generating-station on the motor-circuits, so that when the motors are operated as momentum-driven generators in braking they may continue to restore energy through the translating device to the supply system as the train slows down. In the particular arrangement shown in the drawings the controlling-switch is designed to change the connection of the trolley-line 6 step by step from the terminal *a* of the storage battery to the terminals *b*, *c*, *d*, and *e*, and finally to completely break the connection between the motors and the source of supply.

The operation of the system as a train approaches a station is as follows: Supposing the controllers on the different cars to be in the position where connection is made to the conductor 12, as soon as the contact-shoes 15 come into engagement with the rail 7 the field-windings of all of the motors on the train will be separately excited from a suitable source of supply (as shown from one of the sections or elements of the translating device) in such a manner that with the train at full speed the motors will generate a poten-

tial slightly in excess of that of the translating device and the supply system connected thereto. The motors operating as generators driven by the momentum of the train will therefore return energy to the supply system. The operation of the motors as braking-generators will cause the train to slow down, thus reducing the electromotive force generated at the terminals; but in the meantime the auxiliary motor 4 will have been started and will have begun to rotate the controlling-switch 2, so as to reduce the tension impressed on the trolley-line from the generating source. By the time that the potential at the motor terminals has fallen below that of the line 18 the controlling-switch 2 will have changed the connection of the trolley-line 6 from the terminal *a* to the terminal *b* of the translating device, thus reducing the electromotive force opposed to the motors operating as braking-generators and permitting them to restore energy to the translating device and through it to the supply system. This operation will continue until finally the trolley-line 6 is connected to the point *e*, after which the connection to the supply system will be opened and, if desirable, the motors may be thereafter short-circuited through a suitable resistance, the train being finally brought to a standstill by the application of the ordinary air or vacuum brakes.

The contacts of the controlling-switch 2 may of course be arranged in any suitable manner to accomplish the desired results, and the translating device may be subdivided to any desired extent. In Fig. 3 I have illustrated one arrangement of contacts that may be used on the switch 2. The arrangement shown in this figure is fully described in German Patent No. 104,016 and hence needs no extended description here, it being sufficient to state that as the switch is moved from the position 1 1 to the position 6 6 the connection of the trolley-line 6 is transferred from *a* to *b*, to *c*, to *d*, to *e*, and finally to *f* or ground through the resistance 33.

During the entire operation of braking the field-windings of the car-motors are being continually supplied with current through the conductors 26 and 27; but as soon as the motor-controllers through which the connections of the car-motors are controlled are turned from the braking position the connection from the auxiliary trolley-conductor 7 through the train-conductor 12 to the motor-fields is broken and the switch 5 returns to its off position, thus opening the circuit of the auxiliary motor 4. At this moment the controlling-switch 2 may be turned back to its zero position by means of weights or springs, the gearing between the switch and the auxiliary motor being released by an electromagnetic clutch in the circuit of the motor, or else, as shown diagrammatically in Fig. 2, a circuit for operating the motor in the reverse direction may be closed through the two contacts *i* and *k* and through an oppositely-wound field-winding.

In order to limit the movement of the auxiliary motor 4 when operating the controlling-switch in either direction, cut-outs comprising movable contacts carried by the cylinder and fixed contacts adapted to engage therewith may be included in the circuit of this motor, the said cut-outs being arranged to open the motor-circuit as soon as the control-switch 2 is brought into its last or into its first position, or else provision may be made, as explained, for example, in German Patent No. 114,048, to limit the movement of switch 2 even when the auxiliary motor continues to operate. These specific details do not constitute essential portions of my present invention, since the desired end may evidently be attained by equivalent devices. They are only mentioned here in order to demonstrate the operation of the entire system. Thus it would be possible to include the auxiliary motor itself in the circuit from 26 to 27 in place of the magnet-switch 5, so that the motor would be supplied with current immediately as soon as the contact-shoes 15 come into engagement with the auxiliary trolley-line 7. Such an arrangement would, however, have the disadvantage that the auxiliary motor would not always be traversed by the same quantity of current, the quantity of current in this circuit being dependent on the number of motors on the train and the resistances of the field-windings of the motors.

It is evidently immaterial whether, as indicated in the above description, a train is arranged with several motor-cars and a given control system for controlling the operation of all the motors or whether locomotives are used; but since train systems comprising several motor-cars are now used on many railway systems I have illustrated my invention as adapted for train-control.

The arrangement of controller-contacts for the controllers on the several cars, as shown in Fig. 4, has already been referred to. In this figure the rectangular contacts shown inside the dotted line 32 represent the movable contacts upon the cylindrical member of the controller and the range of circular contacts indicates the fixed fingers of the controller. The controllers on each of the several cars are connected by a conducter to the train-line 13 and through it and the trolley-shoes 14 to the trolley-line 6. The arrangement of the controller-contacts (shown in Fig. 4) is one of the arrangements commonly used for series-parallel control of two motors, and hence requires no detailed description. The three rectangular contacts in the last controller position coöperate with the three fingers 29, 30, and 31 to make the connections to the conductor 12, as diagrammatically illustrated in Fig. 1.

It remains to be mentioned that the resist-

ances 16 from the train-conductor 12 to the motors are only put in for the purpose of avoiding any possible slight inequalities in the magnetic properties of the separate motors, such as would cause an uneven load of the same when running or braking, as would necessarily be the case if line 12 were directly cut in as a short-circuited compensating-line between the armatures and fields of all the motors.

The proper arrangements to be made on a road with several stations is illustrated in Fig. 5, in which A B C are three stations, each one of which is provided with a battery and two switching devices of the kind described above—that is, one for the trains coming in from the right and another for those coming from the left. The battery can naturally be common to both switches, as clearly indicated in the drawings.

If then a train arrives within braking distance before a station, the above-described proceeding takes place automatically and without attention on the part of the conductor—that is, the speed of the train will continually decrease until finally the conductor cuts out the current just before the station and brings the train to standstill. The length of the braking distance, as well as the speed at which the auxiliary motor actuates the battery-switch, can be easily determined in advance by calculation for given conditions, the same then always remaining alike for these operating conditions. If, however, a train does not arrive as an exception with regular speed at the auxiliary line—that is, if it has not the speed which was presumed to obtain a correct braking—then no disturbance is produced in the operation, as the battery first gives off current to the train, a return of energy to the battery from the motors only taking place when the tension of the armatures exceeds the existing battery-tension. Thus a train can never come to a standstill before it reaches the station if not intentionally desired.

In the same manner as the braking of the train is effected in the above-described system the starting of the same may be reversely effected (and then the cutting in of resistance in starting the motors could be avoided) in the manner described in German Patent No. 104,016, above referred to. In this case it would be necessary to modify somewhat the arrangement for controlling the operation of the auxiliary motor 4, so that the controlling-switch 2 might be left in its last position until the operator is ready to start the train. This might be accomplished by using the arrangement shown in Fig. 1, with the addition of a simple switch for closing the circuit of the auxiliary motor for rotation in the reverse direction, either using the same field-winding reversely connected, or a separate field-winding, as shown in Fig. 2. This additional switch may be placed under the control of the train-starter at the station, so that the train cannot be started until this switch is closed; but evidently the switch may be electromagnetically operated from the train itself by providing another auxiliary contact-rail or trolley-conductor, like 7, on the side of the station from which the train departs with another electromagnetically-operated switch, like 5, arranged to close the circuit of the auxiliary motor for operation in the reverse direction, and with another contact shoe or shoes connected to one of the members of a controlling-switch on the train, the other member being connected to the other side of the circuit through ground. The use of series motors, however, offers so many advantages in railway operations and otherwise for most power-transmitting purposes that we here omit a further description of such a modification. Furthermore, the economy which could be obtained by switching in batteries when starting the train would only amount to a few per cent. and would not come into question in comparison to the saving when braking.

It is of course possible to entirely separate the fields of the car-motor by a special operation of the car-controllers from the armatures and to then cut in the battery group in the same manner as hitherto between the auxiliary rail and earth, so that the motors will run, when braking, as purely separately excited motors. The described arrangement has only been mentioned on account of its simplicity, but any other system of connections would naturally come within the scope of my invention, which requires only a separately-excited motor with the armature connected to a trolley-wire, together with means whereby the tension on the trolley-wire is gradually decreased step by step. The excitation of the motor-fields could also be effected from an auxiliary-current source on the train itself instead of from a fixed source through the auxiliary-trolley conductor.

With the trolley-conductor divided into sections, as shown in Fig. 5, and with each section connected to the source of supply through its own controlling-switch, it will be seen that it is practically impossible for two trains following one another on the same track to come into collision, for supposing it is attempted to start a train from the station A, for example, while another train is still at the station B, the motors of the first train will be deprived of current as soon as the contact-shoes come into engagement with the section 6^2 of the trolley-conductor, because the running of the train into the station B will have reduced the potential on the section 6^2 of the trolley-conductor to zero. The train will merely drift until the contact-shoes 15 come into engagement with the rail 7^2, when the braking connections will be completed.

From the foregoing description it will be evident that very material modifications may

be made in the system, as illustrated in this application, without departing from the spirit and scope of my invention in its broader aspect, and in the following claims I have attempted to define the different elements and combinations of elements that go to make up the system, both in broad and narrow terms, in such a manner as to clearly indicate the scope of the invention. For example, in some of the claims the controlling-switch 2 is defined as a means for connecting the propelling-motors in successively-varying relations to the subdivided source of electromotive force, and evidently any means which will accomplish this object may be substituted in place of the particular controlling-switch which I have shown. The motor 4 is termed a motive device, or an electromotive device, or an electrically-controlled means for operating the controlling-switch or the switch-contacts of which it is made up. The switch 5 I have termed an electrically-actuated device or an electrically-controlled means for controlling the operation of the motive device, or in case the motive device is electrically operated for connecting it to a suitable source of supply. All the connections which are necessary for controlling the operation of the motive device 4 through the medium of the switch 5 I have in certain of the claims included under the designation "means for controlling the operation of the motive device," while in other claims I have included all these connections under the term "electrical control system." The main trolley-conductor and its accessories I have termed a "motor-supply system." In the system which I have illustrated the same circuit which supplies current to actuate the switch 5 also supplies current to separately excite the motor-fields. It will be evident, however, that these two circuits might well be separate and distinct, and in certain of the claims I have so treated them.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In combination, a subdivided source of electromotive force, one or more motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, a motive device for operating said switch, and electrically-operated means for controlling the operation of said motive device.

2. In combination, a subdivided source of electromotive force, one or more motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, an electromotive device for operating said switch, and electrically-controlled means for connecting said electromotive device to a source of current-supply.

3. In combination, a subdivided source of electromotive force, one or more motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, an electromotive device for operating said controlling-switch, a switch for controlling the supply of current to said electromotive device, and means for operating said switch from a distant point.

4. In combination, a subdivided source of electromotive force, one or more motors, means for connecting said motor or motors in successively-varying relations to said subdivided source, and an electrical control system for controlling the operation of said connecting means.

5. In combination in an electric-railway system, a subdivided source of electromotive force, a car or train equipped with one or more propelling-motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, an electromotive device for operating said switch, and means including switch-contacts on the car or train, and a contact-shoe engaging a conductor along the roadway for controlling the operation of said electromotive device.

6. In combination in an electric-railway system, a subdivided source of electromotive force, a car or train equipped with one or more propelling-motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, a motive device for operating said switch, an electrically-actuated device for controlling the operation of said motive device, and means including switch-contacts on the car or train and a contact-shoe engaging a conductor along the roadway for controlling the operation of said electrically-actuated device.

7. In combination in an electric-railway system, a subdivided source of electromotive force, a car or train equipped with one or more propelling-motors, a controlling-switch for connecting said motor or motors in successively-varying relations to said source, an electromotive device for operating said switch, electrically-controlled means for connecting said electromotive device to a source of supply, and means including switch-contacts on the car or train, and a contact-shoe engaging a conductor along the roadway for supplying current from a suitable source to operate said electrically-controlled means.

8. In combination, a vehicle or train provided with one or more propelling-motors, a supply system therefor, a generating source, a subdivided source of electromotive force located at a point along the way and connected to said generating source, a controlling-switch constructed and arranged to connect the said motor-supply system either across the generating source or across different portions of the subdivided source, a motive device for operating said controlling-switch, and means including proper circuit connections and contact devices carried by the car or train for controlling the operation of said motive device.

9. In combination, a vehicle or train provided with propelling-motors, a supply sys-

tem therefor, a generating source, a subdivided source of electromotive force located at a point along the way and connected to said generating source, means for separately exciting the fields of the propelling-motors, a controlling-switch constructed and arranged to connect the said motor-supply system either across the generating source or across different portions of the subdivided source, and means for operating the said controlling-switch.

10. In combination, in an electric-railway system, a car or train provided with one or more propelling-motors, a subdivided source of electromotive force located at a point along the way, and connected across the source of supply, a controlling-switch connected between the source of supply and the propelling-motors, and having its contacts arranged to connect the motor-circuits to one or the other of the terminals of the subdivided source, a motive device for operating said controlling-switch, and an electrical control system including proper circuit connections and contact devices carried by the car or train for controlling the operation of said motive device.

11. In combination in an electric-railway system, a vehicle or train provided with one or more propelling-motors, a supply system therefor, a generating source, a subdivided source of electromotive force located along the way and connected to said generating source, switch-contacts for connecting said motor or motors in successively-varying relations to said subdivided source, means for actuating said switch, and an electrical control system including proper circuit connections and contact devices carried by the car or train for controlling the operation of said actuating means.

12. In combination in an electric-railway system, a generating source, a subdivided source of electromotive force located along the way and connected to said generating source, switch-contacts for connecting said motor or motors in successively-varying relations to said subdivided source, means for actuating said switch-contacts, an electrical control system for controlling the operation of the said contact-actuating means, and circuit connections for supplying current at constant potential to the field-windings of said motor or motors.

13. In combination in an electric-railway system, a generating source, a subdivided source of electromotive force located along the way and connected to said generating source, switch-contacts for connecting said motor or motors in successively-varying relations to said subdivided source, electrically-controlled means for actuating said switch-contacts, and an electrical control system, including an electromagnetic switch, a conductor along the way, a contact shoe or shoes carried by the car or train, and switch-contacts on the car or train, for controlling the operation of the said contact-actuating means.

14. In an electric-railway system, a generating source, one or more subdivided sources of electromotive force located along the way, a controlling-switch connected to each of said sources, a sectional trolley-conductor having a section corresponding to each subdivided source and arranged to be connected to some one of the terminals of the subdivided source through the contacts of the said controlling-switch, electrically-controlled means for actuating said controlling-switch, and an electrical control system including a section of conductor at the point at which it is desired to stop the car or train, and contact-shoes and suitable circuit connections for securing the operation of the said controlling-switch-actuating means.

15. In an electric-railway system, a sectional trolley-conductor, a separate subdivided source of electromotive force for each section of said conductor, and a controlling-switch for controlling the connection between each of said sections and the corresponding subdivided source.

16. In an electric-railway system, a sectional trolley-conductor, a separate subdivided source of electromotive force for each section of said conductor, and a controlling-switch for connecting said trolley-conductor in successively-varying relations to said subdivided source.

17. In a regenerative system for braking an electrically-operated car or train, a sectional trolley-conductor, each section extending from one station into the next in advance, a separate subdivided source of electromotive force for each section, a controlling-switch for each section constructed and arranged to connect the section in successively-varying relations to its corresponding source, and an electrical control system including a second sectional conductor extending from the braking distance into the station and suitable circuit connections and electrically-actuated devices for securing the operation of the controlling-switch.

18. In a train system, a train-conductor, a contact shoe or shoes connected therewith, means on each motor-car of the train for connecting the field-windings of the motors on that car to said train-conductor, and a compensating resistance in circuit between each field-winding and the said train-conductor.

19. In an electric-railway system, a car provided with a plurality of motors, a main trolley-conductor and contact-shoe, an auxiliary conductor and contact-shoe, and means for connecting the field-windings of all of the motors in multiple to said auxiliary conductor through the corresponding contact-shoe.

In witness whereof I have hereunto set my hand this 30th day of September, 1901.

MARTIN T. A. KUBIERSCHKY.

Witnesses:
WOLDEMAR HAUPT,
HENRY HASPER.