No. 702,981. Patented June 24, 1902.

F. A. MERRICK & E. W. STULL.

CONTROL OF ELECTRIC MOTORS.

(Application filed Sept. 10, 1901.)

(No Model.) 3 Sheets—Sheet 1.

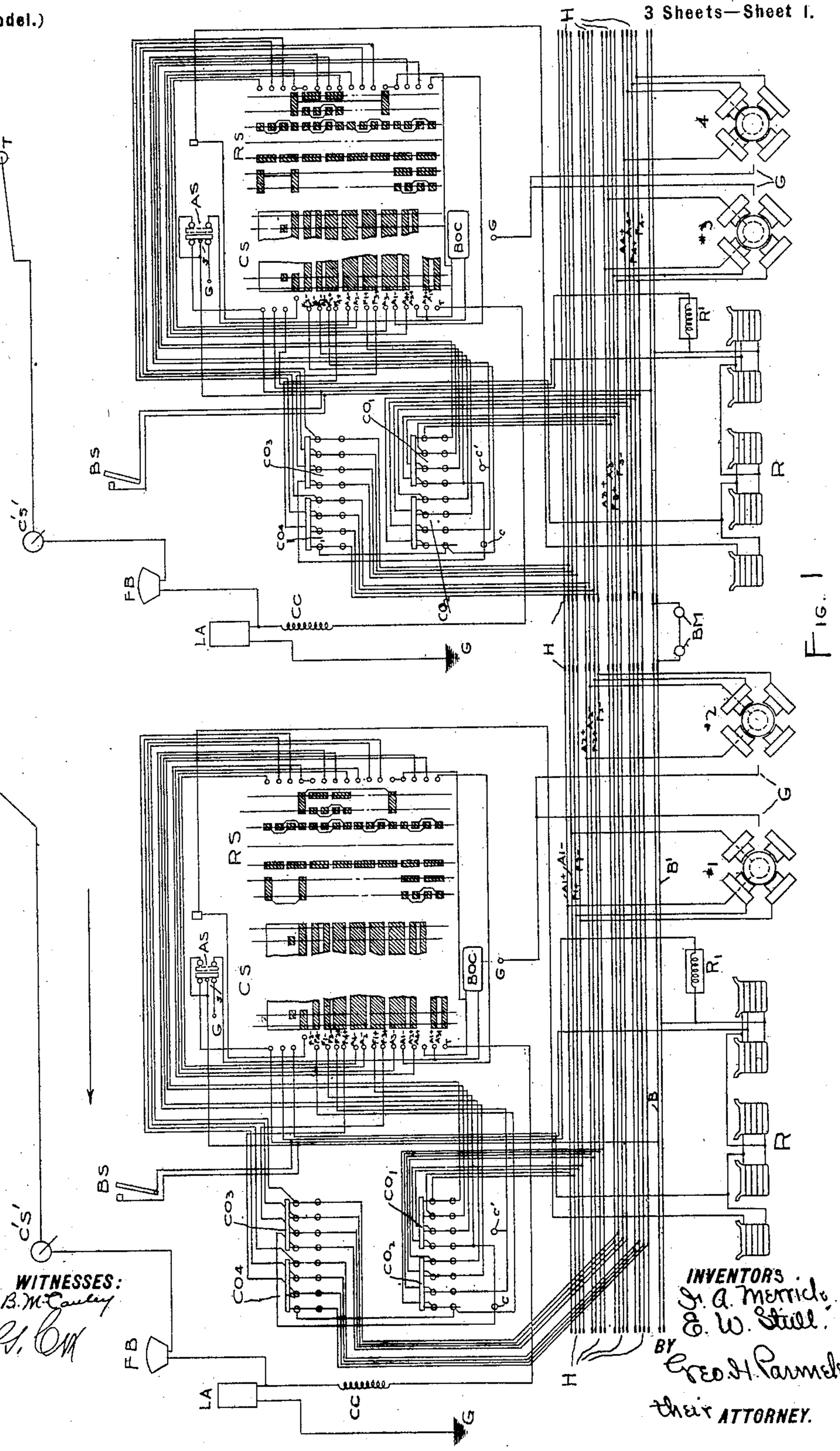

FIG. 1

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(No Model.) 3 Sheets—Sheet 2.

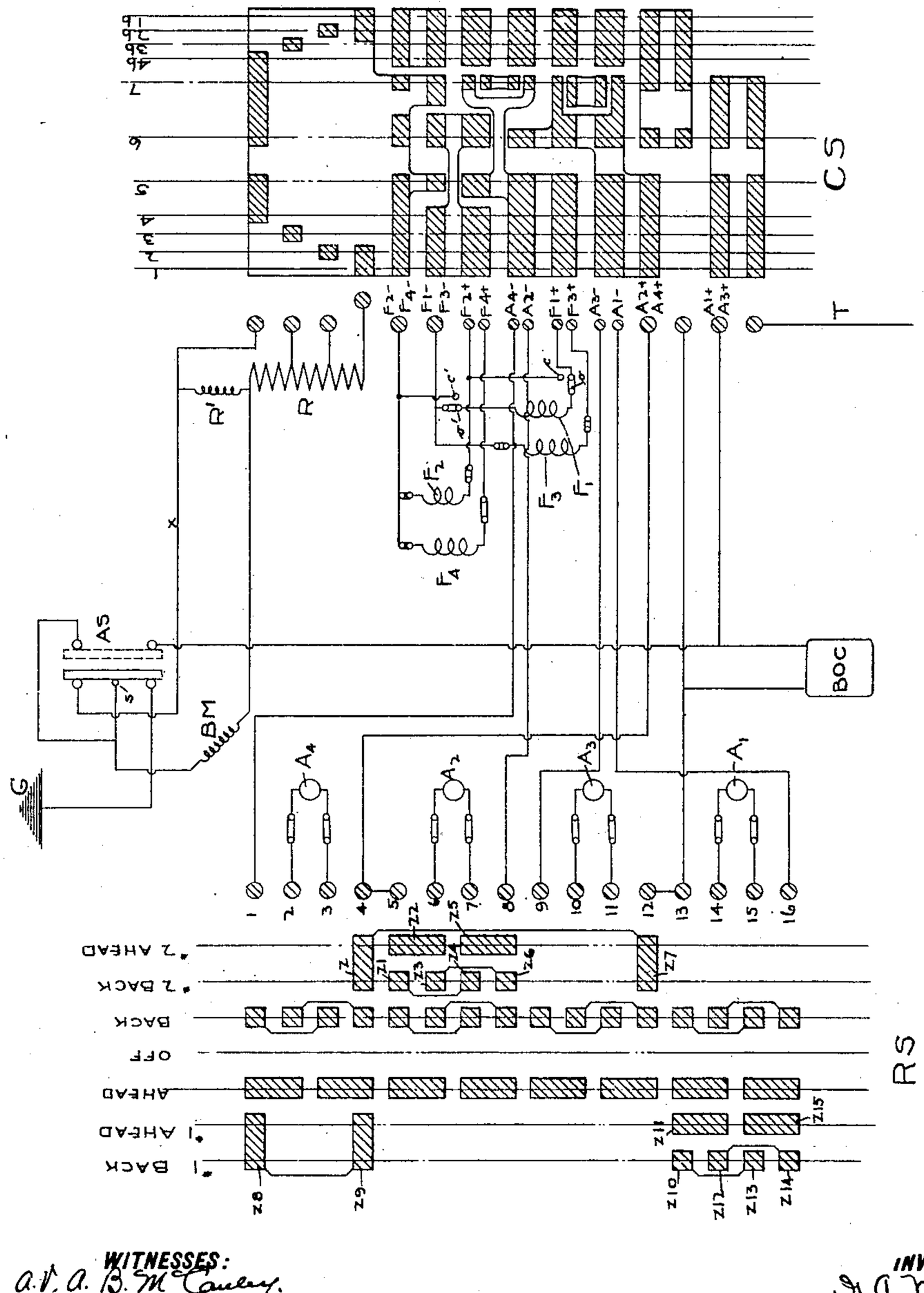

FIG. 2

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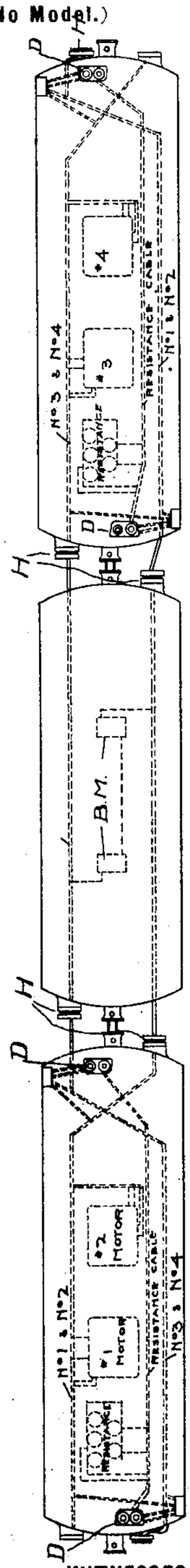

FIG. 3

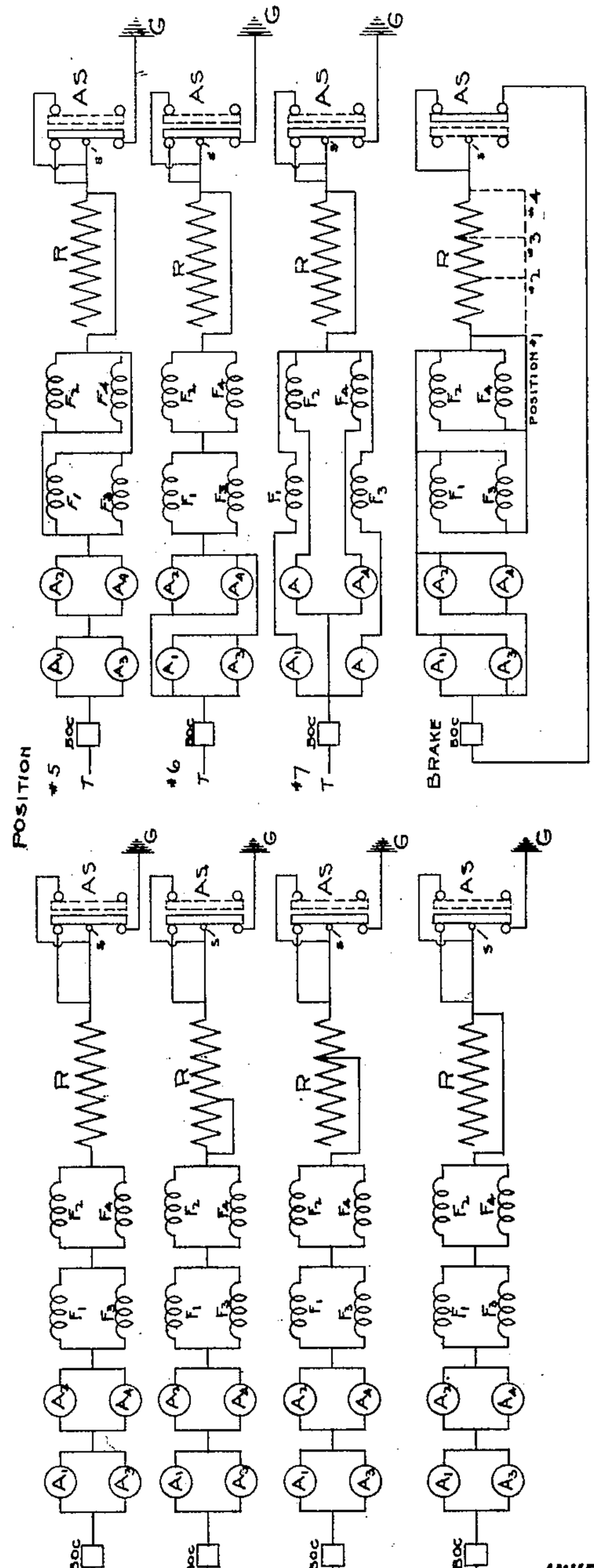

FIG. 4

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UNITED STATES PATENT OFFICE.

FRANK A. MERRICK AND EMMETT W. STULL, OF JOHNSTOWN, PENNSYLVANIA, ASSIGNORS TO THE LORAIN STEEL COMPANY, A CORPORATION OF PENNSYLVANIA.

CONTROL OF ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 702,981, dated June 24, 1902.

Application filed September 10, 1901. Serial No. 74,972. (No model.)

To all whom it may concern:

Be it known that we, FRANK A. MERRICK and EMMETT W. STULL, of Johnstown, in the county of Cambria and State of Pennsylvania, have invented a new and useful Improvement in Control of Electric Motors, of which the following is a full, clear, and exact description, reference being had to the accompanying drawings, which form a part of this specification.

Our invention has relation to the control of electric motors, and more particularly to a system of control for use on electric railways where cars are run in trains, in which one car or more than one or all the cars are equipped with propelling-motors.

The invention is designed to simplify the controlling means by dispensing entirely with the use of master-controllers and with pilot-motors or other devices controlled by the master-controllers for actuating the individual motor-controllers and to effect the circuit changes which vary the speed, power, and braking action of the motors directly by means of manually-operated controllers mounted on the car-platforms.

Generally considered, our system consists in providing means of the novel character hereinafter more fully described, and pointed out in the claims, whereby all the motors throughout the train may be controlled from any car of the train in the same manner as if they were all mounted upon a single car by the operation of a unitary controlling mechanism as distinguished from the simultaneous or concurrent operation of a number of controllers throughout the train. Each motor-car is provided with one or more of these unitary controlling mechanisms, any one of which may be selected as the operating one, and any motor-car may be run singly or in connection with a number of trailers as well as in connection with other motor-cars, the controllers being arranged each to control all the motors for which it is constructed or a less number. Included in the system are means whereby the motors of any car may be disconnected from the circuit at any time without detaching the car from the train and without interfering with the operation of the motors of the other cars, and also means whereby when any car is being run singly or in connection with trailers only one of its motors may be removed from circuit if disabled.

As a further part of the system we arrange the car-wiring in such a manner that it is the same on each motor-car and the cars may be connected up in a train without regard to end relation or to particular location in the train.

Our invention also consists in the novel construction, arrangement, and combination of parts, all as hereinafter described, and pointed out in the appended claims, reference being had to the accompanying drawings. In these drawings we have shown the invention as applied to a train composed of two motor-cars and an intermediate trailer-car, each of the motor-cars being equipped with two motors. As will appear hereinafter, our invention is not, however, limited to a train of this particular composition.

Figure 1 is a diagram showing the car and train circuits. Fig. 2 is a diagram which represents in a simpler form the circuits of Fig. 1, all the controllers except the one which is being operated being omitted. Fig. 3 is a diagram showing the general arrangement of car and train wiring, and Fig. 4 is a series of diagrams illustrating the motor-circuits in the different power and brake positions of the controller.

In Fig. 3 each of the motor-cars is shown as having two controllers, one at each end, connected in multiple in the circuit; but in Fig. 1, owing to lack of space, only one controller is shown on each car, and this, in fact, will in some cases be the arrangement in practice. To further economize space in Fig. 1, the train-wires which run from the intermediate trailer-car are shortened beyond their true proportions and the developments of the controller-drums are partially broken away. The full development is, however, shown in Fig. 2, in which the circuits may be very easily traced.

In these diagrams the letter T wherever seen indicates the connection by trolley or otherwise with the supply-circuit, and G indicates ground or return connections.

C'S' indicates canopy-switches; LA, lightning-arresters; CC, choke-coils, and BOC blow-out coils.

The four motors are respectively designated as No. 1, No. 2, No. 3, and No. 4, their armature-coils being further designated as A', A^2, A^3, and A^4, respectively, and their field-coils F', F^2, F^3, and F^4, respectively.

D, Fig. 3, indicates the casings of the motor-controllers; CS, the developments of the controlling-switches; RS, the developments of the reversing-switches, and CO', CO^2, CO^3, and CO^4 cut-out switches, one for each of the four motors.

R R' indicate resistance-coils, BM brake-magnet coils, and BS switches for closing the braking-circuit when the cars are run singly, as hereinafter described.

AS indicates auxiliary switches, the purpose of which will hereinafter appear.

The controlling-switches CS are preferably of the type described and claimed in our Patent No. 681,453, dated August 27, 1901, in which the movable contact-carrying members are each provided with a plurality of contacts which coöperate with relatively stationary contact-fingers and circuit connections to connect the motor elements (field and armature coils) in groups, in which the individual elements in each group are in parallel with each other, and to connect said groups or certain of them either in series or in parallel and also to connect the motors as a whole in parallel. Other contacts brought into operation by a reverse movement of the switch from its off position are properly arranged to connect the motors in parallel in a closed local circuit for braking purposes. The several running power positions of the controlling-switches are indicated by the broken vertical lines on Fig. 2, numbered from "1" to "7," inclusive, and the braking positions are indicated by the lines 1^b, 2^b, 3^b, and 4^b. The reverse-switches RS are, with respect to the two positions marked "Ahead" and "Back," substantially the same as in the said patent, and the armature-coils are connected thereto in a similar manner. The reverse-switches are also provided with certain other positions, which will be described hereinafter.

Referring now to Figs. 1 and 3 and assuming the train to be running in the direction indicated by the arrows on Figs. 1 and 3, it will be noted that there are two cables which run throughout the train, the connections being made between the cars by means of suitable couplings H. One of these cables, which in Fig. 3 is marked "No. 1 and No. 2 cable," is composed of the conductors to which are connected the leads from the elements of motors No. 1 and No. 2, and the other, which is marked "No. 3 and No. 4 cable," is composed of the conductors to which are connected the leads from the elements of motors No. 3 and No. 4. In order to facilitate tracing these connections, we have marked the train-wires in Fig. 1 with reference-signs which correspond to the reference characters which designate the several motor elements, with the sign of the respective motor-terminal added. Thus the train-wire to which the positive terminal of armature-coil A' is connected is marked "A'^+," and the conductor to which its negative terminal is connected is marked "A'^-," &c. We have also marked the stationary contact-fingers of the two controlling-switches (shown in Figs. 1 and 2) with corresponding reference characters. The connections from the terminal of each motor lead from these fingers to the corresponding train wires or conductors through the respective cut-out switches, the armature connections also being through the reverse-switches. It will be noted, however, that while at the front controller the leads for each motor are connected to the train-wires having corresponding reference characters, at the rear controller the corresponding leads go to a different group of train-wires—that is to say, the leads from fingers A'^+ A'^- F'^+ F'^- of the front controller go respectively to the correspondingly-marked train-wires, while the leads from the rear controller go respectively to train-wires marked A^{3+} A^{3-} F^{3+} F^{3-}. The leads A^{2+} A^{2-} F^{2+} F^{2-} from the front controller connect with the correspondingly-marked train-wires; but the corresponding leads of the rear controller connect with train-wires A^{4+} A^{4-} F^{4+} F^{4-}. The leads A^{3+} A^{3-} F^{3+} F^{3-} from the front controller go to the correspondingly-marked train-wires, while the corresponding leads from the rear controller go to train-wires marked A'^+ A'^- F'^+ F'^-, and the leads A^{4+} A^{4-} F^{4+} F^{4-} from the front controller go to the corresponding train-wires, while from the rear controller they go to wires A^{2+} A^{2-} F^{2+} F^{2-}. By reason of this arrangement it will be apparent that if the train be operated from the controller at the rear end of the train former motors No. 3 and No. 4 become, in effect, motors No. 1 and No. 2, and former motors No. 1 and No. 2 become, in effect, No. 3 and No. 4. This arrangement enables all the controllers to be exactly alike. The cut-outswitches on all the cars may be arranged, numbered, and connected with their respective controllers in the same manner, and the general arrangement of the car-wiring may be the same for all the motor-cars. This not only avoids confusion to the motorman which would result from the various switches being differently arranged and differently marked on the several cars, but it also makes the location of any car on the train immaterial as affecting the operation of control. The advantage of the arrangement may, perhaps, be illustrated by noting the fact that it is by reason of it that the diagram in

Fig. 2 is perfectly accurate as representing either the front or the rear controller as being the one in use.

In order that the cars may be coupled up in the train without regard to end relation, No. 1 and No. 2 cable and No. 3 and No. 4 cable are crossed on each motor-car in a manner well known in the art.

The cut-out switches indicated in the drawings are substantially like those shown in our said patent, except that a separate switch is provided for each motor instead of one switch for each pair of motors. The cut-out switches for No. 1 and No. 2 motors are also provided with an additional contact *c* or *c'*, the purpose of which will presently be described. In Fig. 2 the cut-out switches are for convenience indicated by conventional representations of separate switches placed in each of the leads of the motor-terminals. The auxiliary switches AS are also substantially the same in their general construction as the similar switches shown in said patent, being arranged to be automatically thrown from "power" to "brake" position and reversely by the corresponding movement of the controlling-switch. The main purpose of these auxiliary switches is to provide simple means for effecting a ground or return connection for the motor-circuits in the power positions of the controlling-switches and to break their connection and close the local circuit of the motors for the braking positions. These switches are also each provided with an additional contact *s*, to which the coils BM of the brake-magnets are connected from the resistance R. This connection is shunted by the resistance-coil R', which is connected to the conductor X, which in positions 4, 5, 6, and 7 completes the ground connection around the resistance R. By reason of the connections just described when the controlling-switch is moved back from the braking to the power positions sufficient current is shunted by the action of resistance R' through the coils BM to neutralize the residual magnetism of the brake-magnets. The general connection of these switches together with their operations are clearly shown in Figs. 1, 2, and 4 and need not be described more in detail.

The brake-magnet coils BM are connected between two train-wires BB', Fig. 1, wire B being connected at both controllers to the contact *s* of the auxiliary switches and wire B' being connected to the resistance-coils R. It will be noted from Fig. 1 that each motor-car is provided with a full set of resistance-coils, each set being connected in the same manner with the controller of its car and with the train-wire B', so that with either controller in use the resistance-coils on that particular car are brought into operation, while those on the other car are open-circuited.

We have shown brake-magnets on the trailer-car only, but obviously they may be used on all the cars connected in multiple between the train-wires B B'. For the purpose of closing the braking-circuits on the motor-cars when they are detached from the train and running singly the hand-switches BS are provided. These switches are connected in the leads from the wires B B' to the contacts *s* of the switches AS and to the controller-switches and are left open when the cars are running in trains.

From the foregoing the manner in which either controller may be operated to control all the motors on the train in the same manner as if said motors were all on the same car will be clear. We will now refer briefly to the manner in which the motor elements are connected in the various positions of the controllers in order that it may also be clear how either controller may be operated for two motors only.

Referring to Fig. 4, it will be seen that in starting from rest the motor elements are all connected in groups whose individual elements are in parallel with each other, and all the groups are connected in series with each other and with the resistance-coils R. At positions 2 and 3 portions of the resistance are removed from circuit, and at position 4 the resistance is entirely removed, the other connections remaining as at position 1. At position 5 the series connection between the two armature groups is maintained, as is also the series connection between the armature and field groups; but the field groups themselves are connected in parallel. At position 6 the series connection of the field groups is restored, but the armature groups are connected in parallel with each other and in series with the field groups. At position 7 each armature is placed in series with its field and the four motors as a whole are connected in parallel. These several motor combinations provide for the necessary range in the power and speed of the motors. The last diagram in Fig. 4 shows the motors connected for braking in a closed local circuit, the armature and field groups being in series with each other and individually in parallel. To avoid multiplicity of diagrams, this one diagram is made to indicate the four braking positions by showing in dotted lines the short-circuiting of successive sections of the resistance R. The manner in which the various motor combinations are effected is fully described in our said patent and is moreover clearly shown by the present diagrams, so that it is unnecessary to trace out the circuits in detail.

It will now be apparent that if the rear car carrying motors Nos. 3 and 4 be detached from the train it will simply open all the circuits leading to the terminals of those two motors without in any manner disturbing the circuits of motors Nos. 1 and 2, and the operation of the front controller will effect precisely the same combinations of these motors that it did before. Likewise the detachment

of the front car will open all the circuits leading to motors Nos. 1 and 2 and the controller on the rear car will operate motors Nos. 3 and 4. In a similar manner if when running in a train the motors of either car or one of them become disabled the opening of the corresponding cut-out switches will leave the circuits in the same condition as if that car had been detached, and the train can be run with the remaining motors. When, however, one of the motor-cars is being run singly or in connection with trailers only and one of its motors becomes disabled, the cutting out of circuit of that motor without interfering with the operation of the remaining motor cannot be effected by merely opening the corresponding cut-out switch, since that would leave the circuit of the other motor broken. We therefore provide the reversing-switches with the additional contacts shown in the positions marked "No. 1 back," "No. 1 ahead," "No. 2 back, "No. 2 ahead," and also provide the cut-out switches CO′ and CO^2 of all the cars with the additional fixed contacts *cc′* before referred to. Suppose that motor No. 1 is to be cut-out. The reverse-switch of the controller being used is moved to position No. 2 ahead (or No. 2 back) and the cut-out switch CO′ is thrown open. Inasmuch as the current for armature A^2 in the operation of the controller for two motors passes through armature A′ before going to armature A^2 the opening of switch CO′ cuts off the trolley connection from A^2; but this is overcome by the additional contacts of the reverse-switch now brought into play. As may be seen from Fig. 2, the current after passing through the blow-out coil BOC from the finger marked A'^+ goes to fingers 13 and 12, thence to contacts z^7 z of the reverse-switch, to fingers 4 and 5, contact z^2, finger 6, armature A^2, finger 7, contact z^5, finger 8, through contacts of switch CS to finger F'^+, through arm *o* of cut-out switch CO′ to contact *c*, to and through field F^2, to switch CS and ground. This shows the purpose of the contact *c* of switch CO′, which when that switch is thrown to its open position is engaged by arm *o*, (which normally forms a part of the connection to field F′,) and thus makes a direct connection to field F^2. This is clearly shown in Fig. 2. The contacts z' z^3 z^4 z^6 of the reverse-switch are arranged to reverse the current through armature A^2 when the reverse-switch is moved to position No. 2 back. If motor No. 2 is to be cut out, the switch CO^2 is thrown open and the reverse-switch is moved to position No. 1 ahead or No. 1 back. The current from trolley T now passes through blow-out coil BOC to finger 13, contact z^{11}, finger 14, armature A′, finger 15, contact z^{15}, finger 16, finger A'^-, through contacts of switch CS to finger A^{3+}, to finger 4, to contacts z^9 z^8, finger 1, finger A^{4-}, through contacts of switch CS to finger F'^+, through contact-arm *o′* to and contact *c′* of cut-out switch CO^2 to switch CS to ground. In this case the contacts z^{11} and z^{15} of the reverse-switch maintain the circuit to and through armature A′, and the contacts z^8 z^9 make a connection around the armature A^2. The contact *c′* and arm *o′* of the switch CO^2 (which coöperate in the same manner as contact *c* and arm *o* of switch CO′) complete the connection from the field F′ to ground. The contacts z^{10} z^{12} z^{13} z^{14} are arranged to reverse the current from the armature A′ when the reverse-switch is moved to position No. 1 back.

In tracing the above circuits it has been assumed that the switch CS is at one of its first four positions, means of any well-known character being provided to prevent said switch from being moved beyond its series positions when but one motor is being used.

The connections effected by means of the contacts *c c′* might be made at the reverse-switch; but to do so would very largely complicate that switch and its connections, since it would be necessary to bring the terminals of the field-coils to that switch, which would require a considerable increase in the number of contact-fingers and contacts.

It is apparent that any number of trailer-cars consistent with the power of the motors may be used, and it will also be seen that the number of motor-cars in the train may be increased. For instance, by providing each controller with two similar switch-drums CS, geared together to revolve in unison by the operation of a single handle in a manner well known in the art, it would be possible to control either one, two, three, or four motor-cars, having two motors each, or by the same provision each of two motor-cars might be equipped with four motors. The system, however, is considered to be more particularly useful in the more limited application thereof, which we have herein shown and described, owing to the multiplication of train-wires and connections which result when the number of motor-cars is increased. It will be also obvious that our invention is not limited to the use of controllers of the specific character herein shown and described, since other types of controllers may be employed which will operate a plurality of motors in groups on multiple circuits, so arranged that the circuit to one or more groups may be opened without affecting the circuit of the remaining group or groups, nor are we limited to various other minor details, all of which may be more or less changed by those skilled in the art without departing from our invention.

Having thus described our invention, what we claim as new, and desire to secure by Letters Patent, is—

1. In a system of train control, the combination with a plurality of train-wires to which the motors are connected, four for each motor, of one or more manually-actuated con-

trollers on each car connected to each train-wire, corresponding leads in the different controllers being connected to different train-wires.

2. In a system of train control, the combination with a plurality of train-wires to which the motors are connected, of one or more manually-actuated controllers on each car connected to each of said train-wires, corresponding contacts of the several controllers being connected to different train-wires.

3. In a system of train control, a plurality of train-wires, one set for each motor, and each motor connected to one set only of said wires, and a controller on each car connected to all of said wires, corresponding contacts of the different controllers being connected to different wires.

4. In a system of train control, the combination of a plurality of train-wires to which the motor elements are connected, one or more controllers on each motor-car each of which is connected to all of said wires, each of said controllers being arranged to control two or more sets or groups of motors on parallel circuits.

5. In a system of train control, the combination of a plurality of train-wires to which the motor elements are connected, and one or more motor-controllers on each motor-car, each of which is connected to all of said wires, said controllers having contacts for connecting corresponding motor elements in groups in which the individual elements are in parallel, and to connect the groups either in series or in parallel.

6. In a system of train control, a plurality of train-wires to which the motors are connected, one or more motor-controllers on each motor-car, each of which is connected to all of said wires, and each of said controllers having contacts arranged to connect the motors and their elements in various ways to vary their power and speed and also their braking action.

7. In a system of train control, a plurality of train-wires, one for each motor-terminal, one or more motor-controllers on each car, each of said controllers being connected to all of said train-wires and arranged to connect the motors of each car both in series and in parallel, and in multiple with the motors of the other car or cars.

8. In a system of train control, a plurality of train-wires, one for each motor-terminal, one or more motor-controllers on each car, each of said controllers being connected to all of said train-wires and arranged to connect the motors on each car both in series and in parallel, and in multiple with the motors of the other car or cars, and also connect the motors in a closed local circuit of variable resistance to run as generators.

9. In a system of train control, a plurality of train-wires, one for each motor-terminal, one or more motor-controllers on each car, each of said controllers being connected to all of said train-wires and arranged to connect the motors of each car both in series and in parallel, and in multiple with the motors of the other car or cars, and also connect the motors in a closed local circuit of variable resistance to run as generators, together with brake-magnet coils included in said local circuit.

10. In a system of train control, a plurality of train-wires, one for each motor-terminal, one or more motor-controllers on each car, each of said controllers being connected to all of said train-wires and arranged to connect the motors of each car both in series and in parallel, and in multiple with the motors of the other car or cars, and also to connect the motors in a closed local circuit of variable resistance to run as generators, together with brake-magnet coils included in said local circuit, and means for neutralizing the magnetism of said coils when said local circuit is opened and the motors are connected with trolley.

11. In a system of train control, the combination with a plurality of train-wires, to which the motor elements are separately connected, one or more motor-controllers on each car, each connected to all of said wires, and arranged to connect the motors of each car in parallel with the motors of the other car or cars, whereby any car may be detached or its motors cut out of circuit without affecting the motors of any other car or cars, together with switches for cutting the motors of any motor-car out of circuit.

12. A motor-controller for train control, consisting of a switch having contacts and connections for controlling a number of pairs of motors in parallel circuits, any one of which may be opened without affecting the others, with the individual motors of each pair on the same circuit, and auxiliary switch mechanism for cutting out a motor of each pair and establishing a circuit through the remaining motor.

13. A motor-controller, consisting of a switch having contacts and connections for controlling a number of pairs of motors in parallel circuits, any one of which circuits may be opened without affecting the others, the individual motors of each pair being in the same circuit, cut-out switches for opening the circuit of any pair of motors or of any motor, a reverse-switch, and additional contacts on the reverse and cut-out switches for completing the circuit through the motor of any pair when the other motor of that pair has been removed from circuit.

14. The combination with a plurality of electric motors, of a controller having contacts and connections for controlling said motors in pairs in parallel circuits, cut-out switches for opening the circuit of any pair of motors or of any motor in each pair, a reverse-switch, and additional switch-contacts

on the reverse and cut-out switches for completing the circuit from either motor to any pair, when its companion motor has been removed from circuit.

15. In a system of train control, the combination of a plurality of independent train-wires to which the motors are connected, a controller on each car connected to all of said wires and having contact devices arranged to connect the motors of that car both in series and in parallel, and in parallel with the motors of the other cars, a cut-out switch on each car for each motor, and reversing-switches having contact devices which coöperate with the cut-out switches to maintain the circuit through one motor only.

In testimony whereof we have affixed our signatures in presence of two witnesses.

FRANK A. MERRICK,
EMMETT W. STULL.

Witnesses:
CORA G. COX,
H. W. SMITH.