other motor or any part of its circuit gives out. These two switches may be thrown up or down, and when the car is in good shape and both motors in use, both switches should be down. Inside the door of every K2, K10, or K11 controller is found a card that tells how to cut out a faulty motor; one motor is called the No. 1 motor and the other the No. 2 motor; the No. 1 motor is the motor on the fuse-box end of the car. Inside the No. 1 controller, the card reads: "*To cut out motor No. 1* (*the motor nearest this end of car*), *throw up left-hand switch as far as it will go. To cut out motor No. 2* (*motor nearest other end of car*), *throw up right-hand switch as far as it will go.*" Inside the No. 2 controller, the card reads: "*To cut out motor No. 1* (*motor nearest other end of car*), *throw up left-hand switch as far as it will go. To cut out motor No. 2* (*motor nearest this end of car*), *throw up right-hand switch as far as it will go.*" The motor cut-out instruction cards read differently on the two ends of the car, because on the front end the No. 1 motor is the front motor and the No. 2 motor is the rear motor; but on the rear end the No. 2 motor is the front motor and the No. 1 motor the rear motor.

39. The shaft of the power drum has on it a stop that is interfered with by a pin operated by the cut-out switch in such a way that when either switch is thrown up, the power drum cannot be moved past the fifth notch. If this were not done, the result would be simply to drop the motor out of circuit when leaving the sixth position and pick it up again on the ninth position if the good motor happened to be the No. 1 motor. If the good motor happened to be the No. 2 motor, as soon as fingers E_1 and G made contact with plates *9* and *10*, Fig. 26, there would be a dead short circuit across the line. The way in which this occurs will be shown later.

40. In Fig. 26, the blades of switch No. *1* are hinged to posts k, l, and m; those of switch No. *2* are hinged to n and p. When switch No. *1* is thrown up, posts k and l are connected by the strip *S S*, and post *m* is dead-ended because the blade attached to it simply overhangs. When switch No. *2* is thrown up, post *n* is connected with the ground post *G* and post *p* is dead-ended.

41. In Fig. 26, both switches are thrown down, so that both motors are cut in and the path of the current on the first notch is $T\text{–}C\text{–}T\text{–}K\text{–}K_1\text{–}R_1\text{–}O\text{–}k\text{–}19\text{–}19\text{–}1'\text{–}A_1\text{–}A\text{–}AA_1\text{–}2'\text{–}F_1\text{–}F\text{–}E_1\text{–}l\text{–}E_1\text{–}E_1\text{–}3\text{–}1\text{–}15\text{–}n\text{–}15\text{–}15\text{–}3'\text{–}A_2\text{–}A'\text{–}AA_2\text{–}4'\text{–}F_2\text{–}p\text{–}F_2\text{–}F'\text{–}G$. If the No. *1* switch is thrown up to the dotted position, the No. 1 motor is cut out and the path of the current is $T\text{–}C\text{–}T\text{–}K\text{–}K_1\text{–}R_1\text{–}O\text{–}k\text{–}SS\text{–}l\text{–}E_1\text{–}E_1\text{–}3\text{–}1\text{–}15\text{–}n\text{–}15\text{–}15\text{–}3'\text{–}A_2\text{–}A'\text{–}AA_2\text{–}4'\text{–}F_2\text{–}p\text{–}F_2\text{–}F'\text{–}G$. If the No. *2* switch is thrown up to the dotted position (No. *1* switch being down), the No. 2 motor is cut out and the path of the current becomes $T\text{–}C\text{–}T\text{–}K\text{–}K_1\text{–}R_1\text{–}O\text{–}k\text{–}19\text{–}19\text{–}1'\text{–}A_1\text{–}A\text{–}AA_1\text{–}2'\text{–}F_1\text{–}F\text{–}E_1\text{–}l\text{–}E_1\text{–}E_1\text{–}3\text{–}1\text{–}15\text{–}n\text{–}G\text{–}G$.

42. If by any chance both switches should be thrown up, thereby cutting out both motors, the path of the current would be $T\text{–}C\text{–}T\text{–}K\text{–}K_1\text{–}R_1\text{–}O\text{–}k\text{–}SS\text{–}l\text{–}E_1\text{–}E_1\text{–}3\text{–}1\text{–}15\text{–}n\text{–}G\text{–}G$. The resistance coil alone would be in circuit, the car could not start, and any advance of the power handle would cause the main-motor fuse to blow unless some part of the controller should blow first. Such an act as cutting out both motors at the same time is an unusual one, but still it has happened with bad results. It must be clearly understood that a cut-out switch should be used only when the power is off. The switch is not built to break any arc, and any attempt to make it do so is apt to result in not only the destruction of the switch itself, but in injury to the operator's eyes.

The cut-out switches on controllers made by different companies vary somewhat in detail and appearance, but they all drop the motor out of the circuit entirely and put a metal path in its place, so that the current has a bridge over which it can cross in order to reach the motor that is not to be cut out.

43. Car-Wiring Diagram for K2 Controllers.—Fig. 27 shows a complete car-wiring diagram for two K2 controllers. *W* is the trolley wheel, *K*, *K* the hood switches, *F B* the fuse box, *L A* the lightning arrester. When the No. 1 controller is on the first notch, the path of the current is: *W–K–K–FB*–choke coil–$O–T–M–T–R_1–R_1–r_1$ through all the resistance $–r_4–R_4–t–19–19–19–1–A_1–A_1–A_1–AA_1–AA_1–AA_1–2–F_1–F_1–F_1–E_1–E_1–E_1–E_1–E_1–c–15–15–15–15–3–A_2–A_2–A_2–AA_2–AA_2–AA_2–4–F_2–F_2–F_2–F_2–E_2–G$. The end E_2 of the No. 2 field is permanently connected to the ground wire. The student should, as an exercise, trace out the paths of the current on the other notches, which are indicated by the dotted vertical lines. The fourth and fifth and the eighth and ninth are the running notches. On the fifth and ninth notches the fields are shunted. In Fig. 27, the wire marked "test line" has nothing to do with the regular controller connections. It simply illustrates a method of locating breaks in the car wiring by using a number of lamps *L*. One end of the test line is connected to the trolley and the free end is touched to the various devices in succession so that the lamps will indicate when the break has been passed.

K11 SERIES-PARALLEL CONTROLLER.

44. Fig. 28 shows the appearance of the K11 controller. This controller is a great deal like the K2, but has two distinguishing features. Its contacts are of larger current capacity, the controller being designed for use with 50-horsepower motors, whereas the K2 controller is intended for use with 35-horsepower motors. The K11 controller is also intended to be used with motors that do not require a shunt, and it is provided with one more resistance notch than the K2. The K2 controller uses a three-part resistance, whereas the K11 resistance has four parts. The K2 controller can handle motors with or without the shunt, the shunt wires being simply left out where no shunts are used, but on

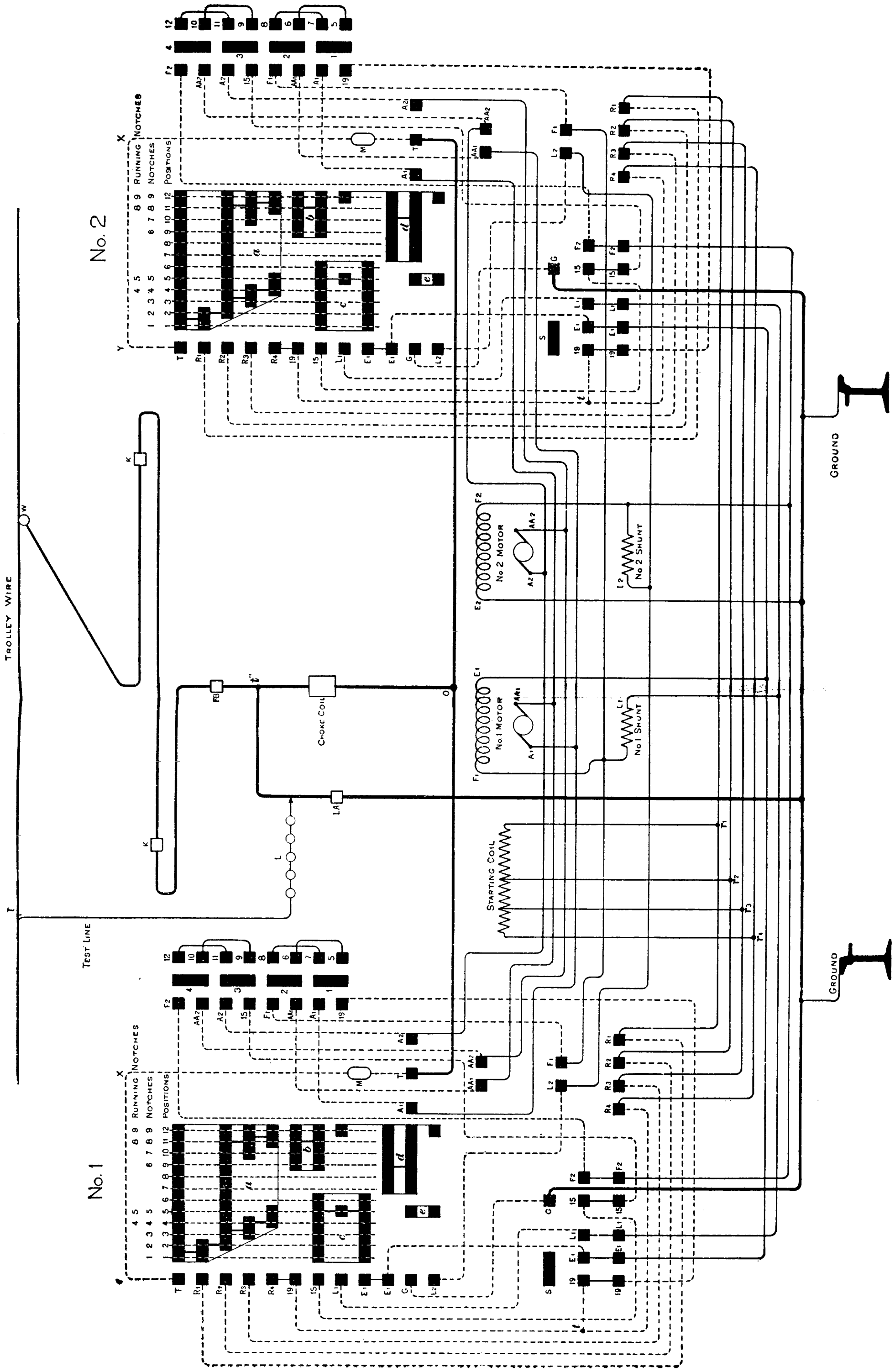

Trolley Wire
Test Line
No. 1
No. 2
Running Notches
Notches
Positions
Choke Coil
Starting Coil
No 1 Motor
No 2 Motor
No 1 Shunt
No 2 Shunt
Ground
Ground

Fig. 27.

the K11 controller there are no shunt fingers or connecting-board blocks provided, so that a shunt cannot be used unless

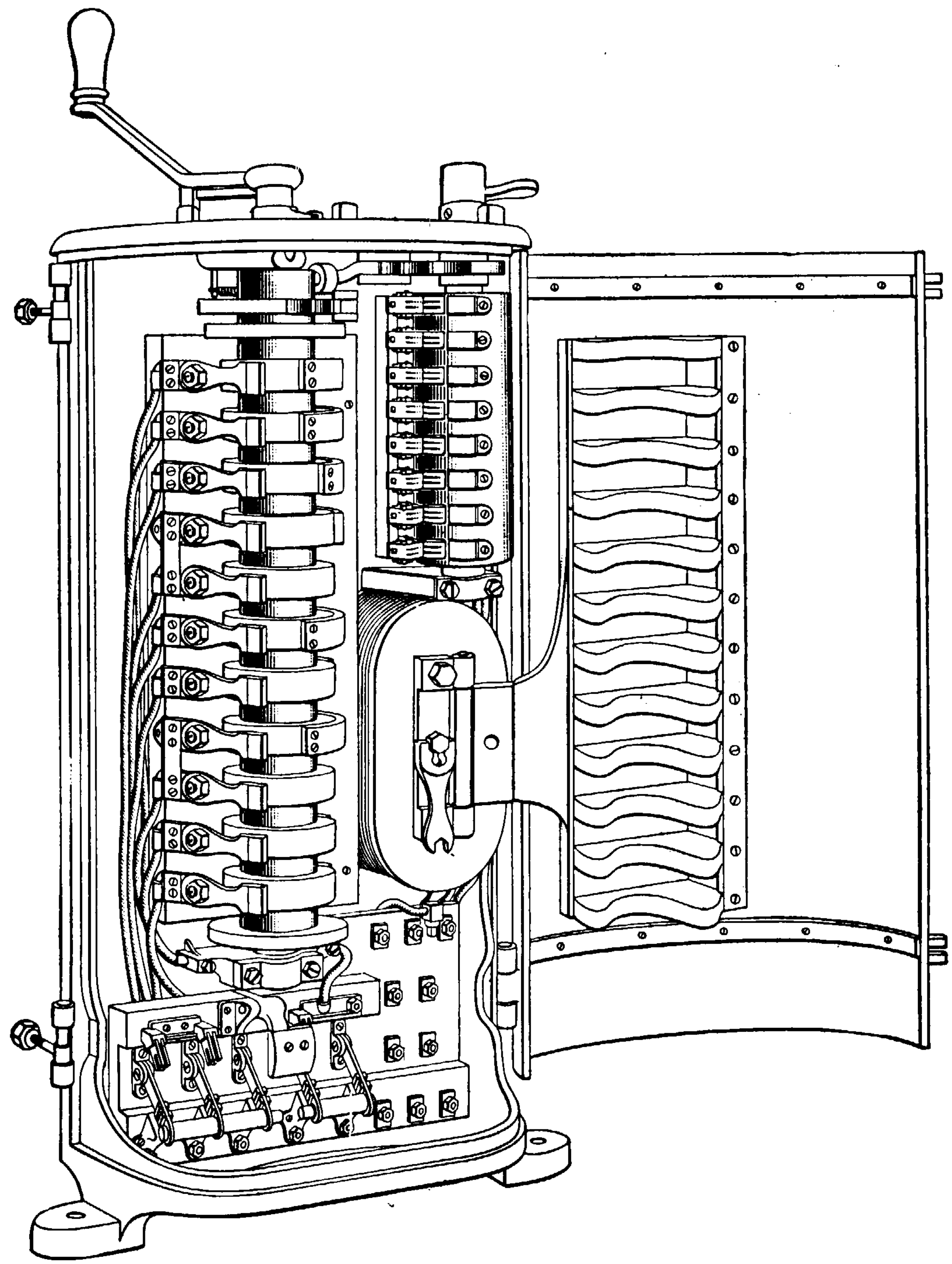


FIG. 28.

both ends of it are permanently spliced to the two field terminals.

45. Fig. 29 gives the combinations effected on all positions of the power drum. There are five notches in series

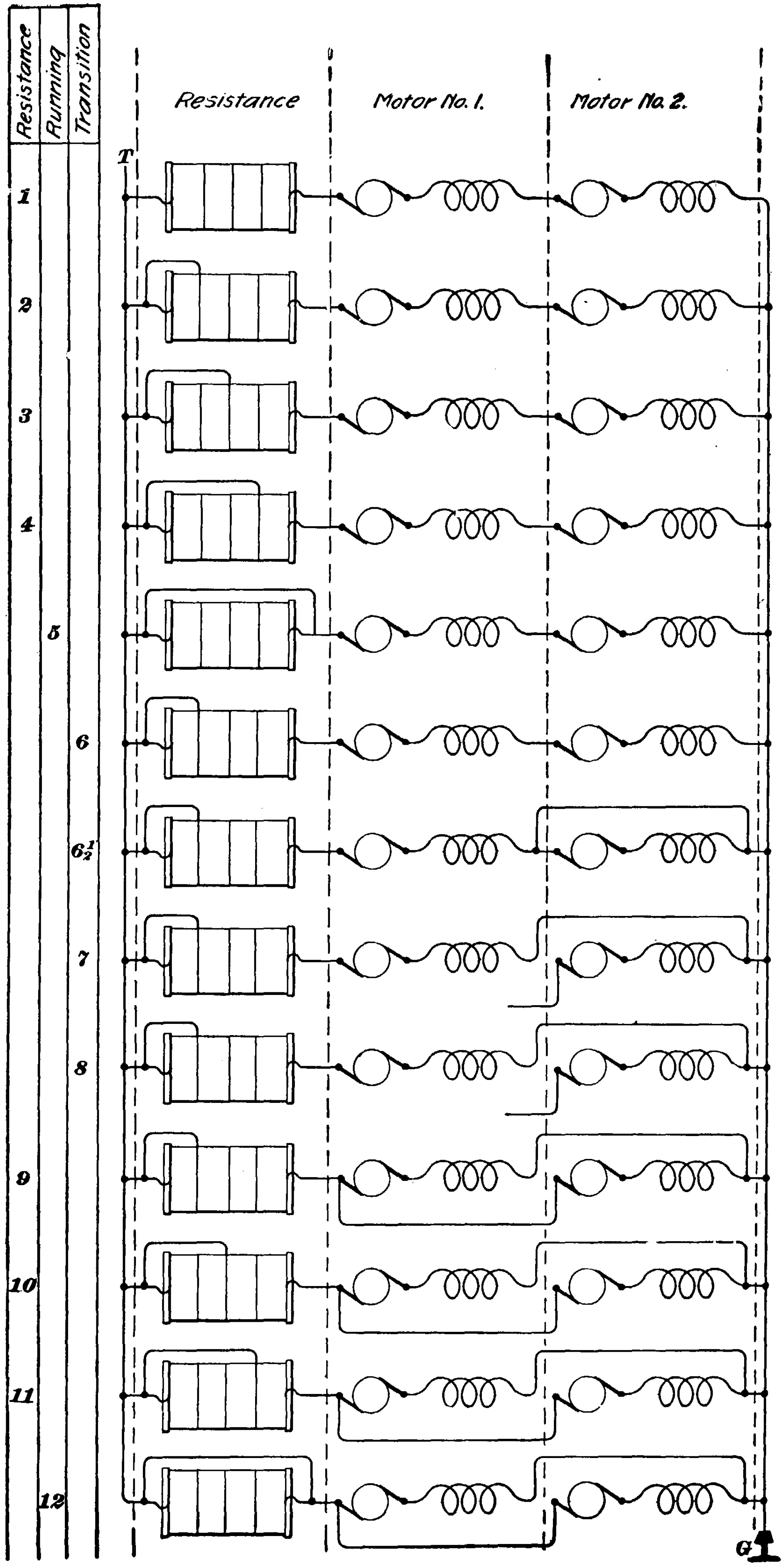
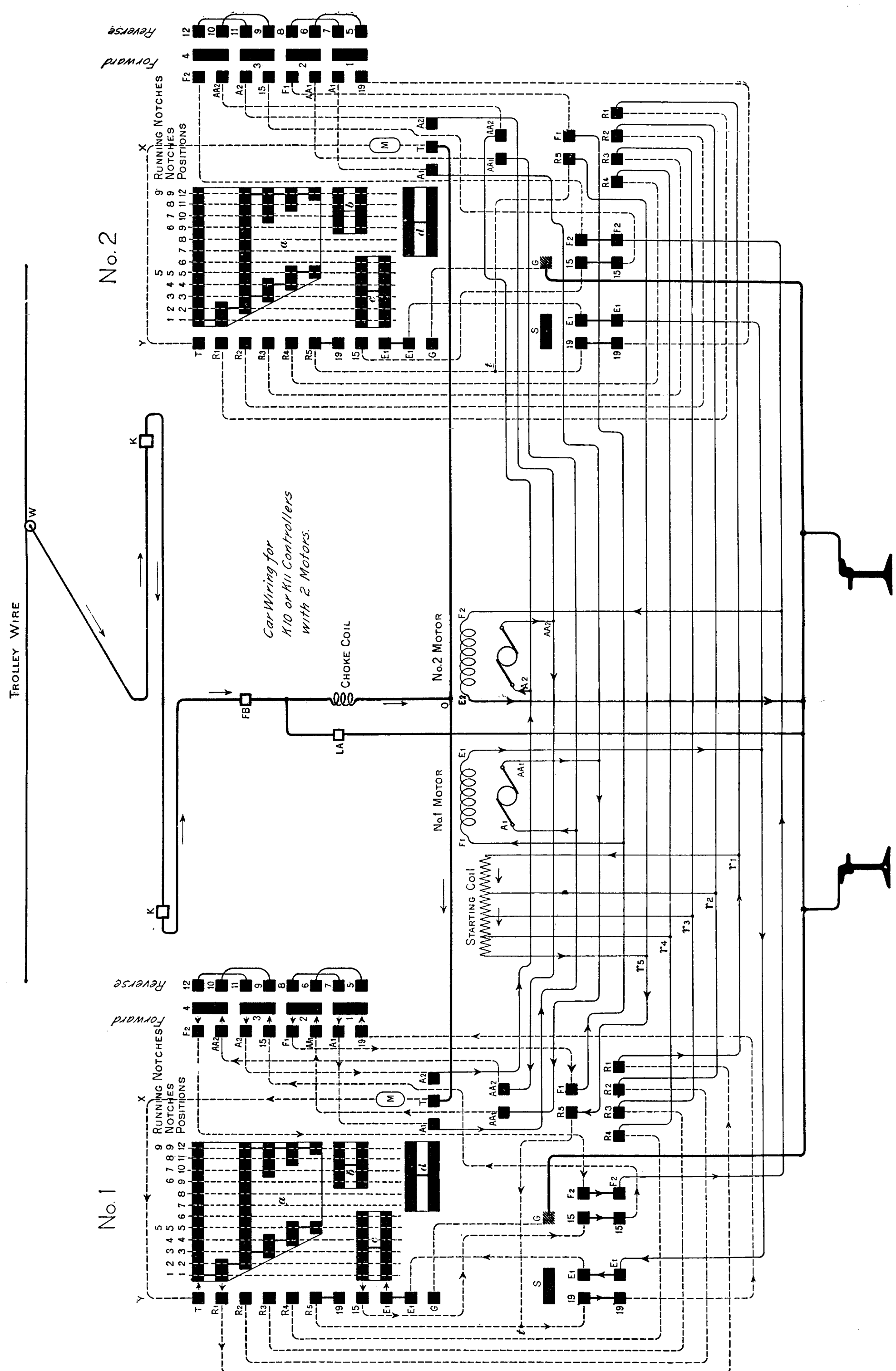

Resistance
Running
Transition
Resistance
Motor No. 1.
Motor No. 2.
T
G
1
2
3
4
5
6
6½
7
8
9
10
11
12

FIG. 29.



Trolley Wire
Car Wiring for K10 or K11 Controllers with 2 Motors.
Choke Coil
No. 2 Motor
No. 1 Motor
Starting Coil
No. 2
No. 1
Running Notches
Notches
Positions
Forward
Reverse

Fig. 30

and four notches in multiple, making a total of nine notches, the same as on the K2 controller. But where the K2 controller has four running notches, two in series and two in multiple, the K11 has only two running notches, one in series and one in multiple. These two running notches are the fifth and ninth.

K10 CONTROLLER.

46. The K10 controller is practically the same in appearance as the K2 and is designed for the same class of work. It has replaced the K2 largely, because shunts are not now used as much as they once were, and the K10 is designed for use without shunts. In fact, it makes the same combinations as the K11, so that Fig. 29 may be taken to represent the various steps. It is a lighter controller than the K11 and is used with 35-horsepower motors. It has four resistance sections, and therefore gives the car a somewhat smoother acceleration than the K2. Fig. 30 shows the car-wiring diagram for two K10 controllers. By comparing with Fig. 27, the student will see that the diagrams are very similar. There is one more section in the starting coil and the shunts are omitted, thus simplifying the controller and its connections to a considerable extent. The running notches are the fifth and ninth. On the fifth notch the motors are in series and all the resistance is cut out and on the ninth they are in parallel and all the resistance is cut out.

WESTINGHOUSE 28A CONTROLLER.

47. The Westinghouse Company has manufactured several types of series-parallel controller that differ considerably in detail from those just described. They now supply controllers of the General Electric type, but quite a large number of their older styles are still in use. We will describe the

28A controller. Fig. 31 shows the Westinghouse No. 38 controller, which is very similar in appearance to the 28A. The different sections of the power drum are separated from each other by vulcabeston insulating rings *U*, *U*, *U*, etc., as

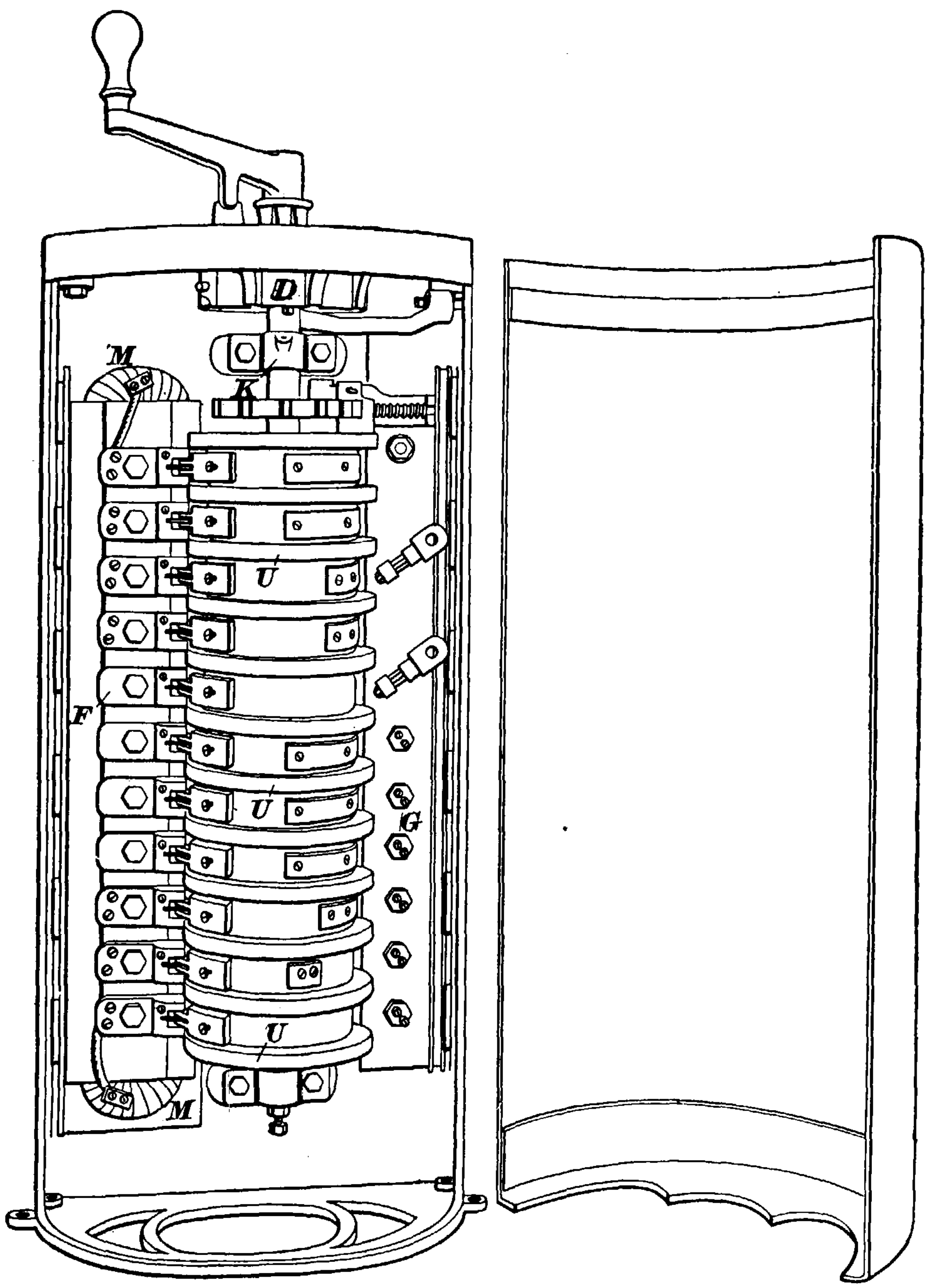


FIG. 31.

shown in Fig. 31. The reverse device, shown at *D*, is of the disk form instead of the drum type, as in the General Electric Company's type K2. The power-drum finger board is on the left at *F*. Around the base of the finger board is wound a magnetic blow-out coil *M*, which, by way of fingers that contain a great deal of iron, projects lines of force across the arc gaps and extinguishes the arcs. The connecting board is in two sections; one section is at *G* in the right-hand part of the controller and the other is in the lower part, below the power drum. As is the case with all modern controllers, the 28A motor cut-outs are arranged so that when one motor is cut out, there is an interference with the power drum in such a way that it cannot be turned past the series notches. With one motor cut out, the 28A controller starts the car on the first notch and gives the single motor full power on the fourth notch. The power and reverse handles interlock as on the K2 and K11 types.

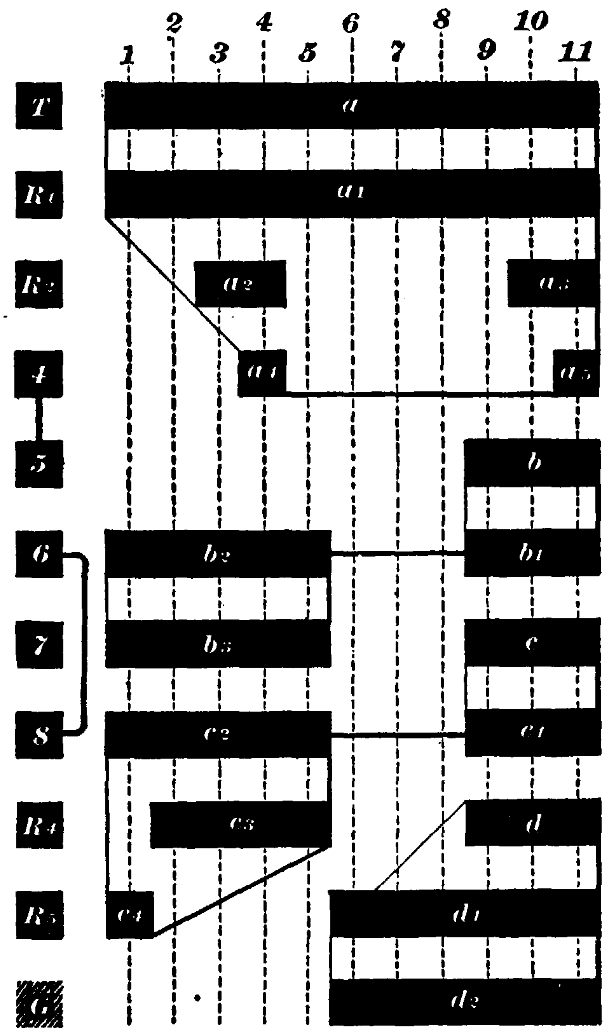


FIG. 32.

48. Fig. 32 shows the 28A power drum and the finger board on the left. This drum has four groups of rings; all rings marked *a* are connected together and should ring up together when tested with a magneto-bell; the same is the case with the rings marked *b*, *c*, and *d*; but groups with different letters are insulated from one another. The vertical dotted lines show the several positions assumed by the drum in going from the first notch to the last one.

49. The 28A Reverse Switch.—On the 28A reverse switch, as on any other, the position of the reverse handle is supposed to indicate the direction in which the car will start as soon as the power drum is turned on.

Fig. 33 shows the connections of the 28A reverse switch. In this diagram, all the devices have been left out save the motors and resistances. All wires, instead of running to their respective controlling devices, as on a car, are here run direct to the reverse switch. The mechanical details of the moving parts of the switch are not shown in Fig. 33, but they can be understood by reference to Fig. 34, which shows the principle on which the switch operates. *D D* is a flat vulcabeston, slate, or fiber disk on the outside rim of which are screwed the brass tips *T*, *T*, *T*, *T*. Handle *H* is pivoted at *O'* and can be moved ahead or back, but in the figure it is in the off-position, in which position it can be taken out. Posts F_1-, A_1+, F_1+, F_2-, A_2-, and F_2+, in Fig. 33, are stationary; besides having connecting posts to which wires can be run, they have switch blades against which brass tips *T*, *T*, *T*, *T*, Fig. 34, press when the handle *H*, and hence the lever *L*, is moved one way or the other. When the handle *H* is shoved ahead to the right, the connections are as shown by the shaded lines in Fig. 33, where F_1+ is connected to post *9*, F_1- to A_1+, F_2+ to post *11*, and F_2- to A_2-. In this position, the path of the current from the trolley *T* to the ground *G* is T-R_1-R_2-R_3-*9* across one of the drum tips to post F_1+, out through the No. 1 motor field, back to post F_1-, across another drum tip to post A_1+, out through the No. 1 motor armature and back through resistance coil R_4-R_5 to post *12*, thence across the dotted line (which indicates that posts *11* and *12* are permanently connected,

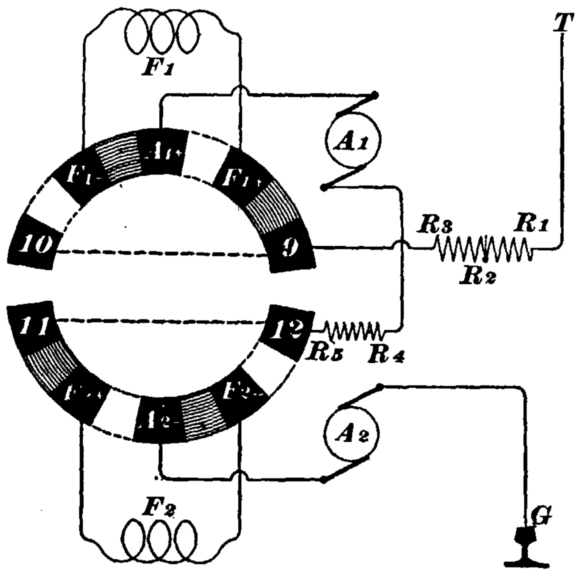


FIG. 33.

as are posts *9* and *10*) to post *11*, through a third drum contact tip to post F_2+, from where it passes out through the No. 2 motor field, back to post F_2-, across the fourth and last drum contact tip to post A_2-, through the No. 2 motor armature to the ground at *G*. This ground is secured by grounding the negative brush lead of the No. 2 motor directly to the frame of the motor or to the ground wire. If the reverse handle *H* is thrown back, the drum contact tips take up the position shown by the dotted lines in Fig. 33, and the former connections are broken. Posts F_1- and *10* are connected together, posts F_1+ and A_1+, F_2- and *12*, F_2+ and A_2- are also connected, and the path of the current from the trolley to the ground is T–R_1–R_2–R_3–*9*–*10*–F_1-, through the No. 1 motor field, F_1+–A_1+, through the No. 1 motor armature, R_4–R_5–*12*–F_2-, through the No. 2 motor field F_2+–A_2-, and through the No. 2 armature to the ground at *G*, as before.

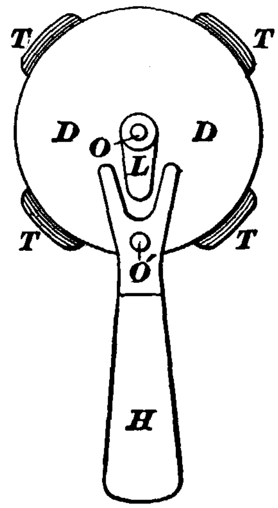


FIG. 34.

50. It should be noticed that when the reverse handle points ahead, the current enters the No. 1 motor field on the right-hand end and the No. 1 armature at the top brush holder; it goes into the No. 2 motor field at the left-hand end and into the No. 2 armature at the lower brush holder. When the reverse handle is thrown back, the current goes into the two armatures the same as it did before, but it goes into the No. 1 field at its left-hand end instead of the right and into the No. 2 field at the right-hand end instead of the left, as it did when the reverse handle was set to send the car ahead. The fields, then, have been reversed instead of the armatures, as on the General Electric equipment.

51. The 28A Cut-Out.—The 28A cut-out consists of two sets of posts, four posts for each motor, with holes in them to take a plug shaped to fit the holes. To operate the cut-out, the plug is taken by the handle, pulled out part of the way, and given a quarter-turn; on releasing the plug, a spring pulls it back home into its new position. The lower plug is for the No. 1 motor, the motor next to the trolley wire, and the upper plug is for the No. 2 motor, the motor next to the ground.

In Fig. 35, both motors are shown cut in, in which position the plugs make contact between the posts that are up and down. For example, the lower plug connects posts *15* and *16* on one side and posts *13* and *14* on the other, the top plug connects posts *17* and *18* on one side and *19* and *20* on the other. Post *20* might just as well not be there, as far as being of any electrical use is concerned, because it is not connected to anything. It is put there not only to avoid having two sorts of cut-out devices in the controller, calling for two sorts of plugs, but it also serves as an additional mechanical support for the top plug, thereby making a good electrical contact more certain. In the position shown in Fig. 35, the path of the current is T–R_1–R_2–R_3–*13*–*14*–F_1+ –F_1- –A_1+ –A_1- –*15*–*16*–R_4–R_5–*17*–*18*–F_2+ –F_2- –A_2- –A_2+ to the ground at G.

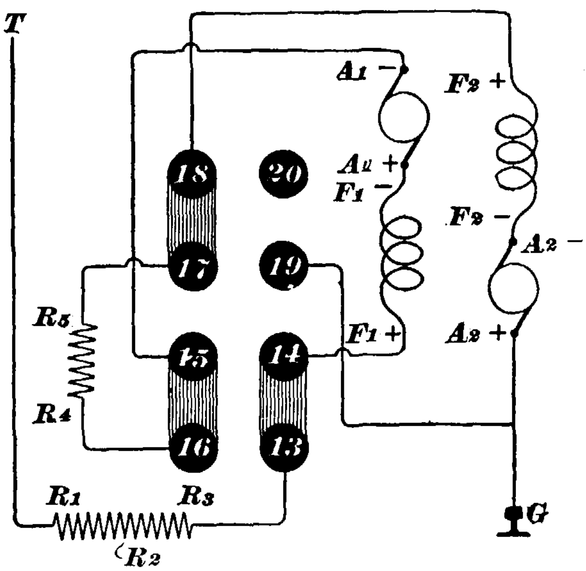


FIG. 35.

It will be noticed that the brush lead at which the current goes into the No. 2 armature is marked A_2-. Of course, the very fact that the current goes in at this brush holder makes it positive, but the lead is marked negative to indicate the fact that because the motors hang on the car truck back to back, their armatures must turn in opposite directions, in order to urge the car in the same direction, and if the current goes into both fields from the same end, it must enter the armatures at the front lead on one motor and at the back lead on the other.

52. In Fig. 36 the No. 1 motor is shown cut out; its plug has been given a quarter-turn, breaking all connection between posts *13* and *14*, and making a connection between the lower posts *13* and *16*, thereby leaving the two ends of the No. 1 motor, connected to posts *14* and *15*, hanging in the air, as it were. The No. 1 motor is, therefore, cut out because it can get no current. The path of the current in this case is T–R_1–R_2–R_3–*13*–*16*–R_4–R_5–*17*–*18*–F_2+–F_2-–A_2-–A_2+ to the ground at G.

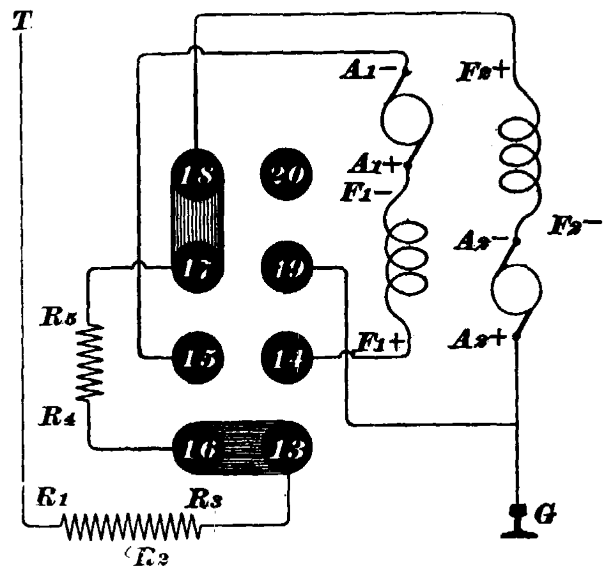


FIG. 36.

53. Fig. 37 shows the No. 1 motor cut in and the No. 2 motor cut out. In this case, a quarter-turn on plug No. 2 has broken the connection between posts *17* and *18* and made connection between posts *17* and *19* direct to the ground at G. One end of the No. 2 motor is left hanging in the air at post *18*, and the other end is grounded through its permanent ground connection. The motor is cut out and therefore dead. The path of the current in this case is T–R_1–R_2–R_3–*13*–*14*–F_1+–F_1-–A_1+–A_1-–*15*–*16*–R_4–R_5–*17*–*19* to earth at G.

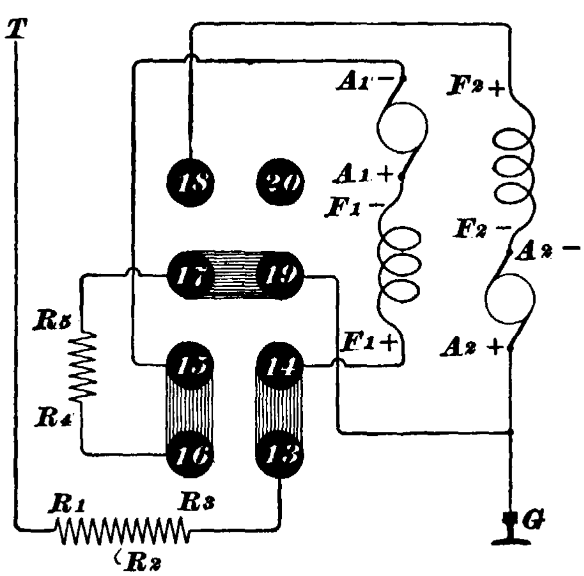


FIG. 37.

54. Car-Wiring Diagram.—Fig. 38 is a car-wiring diagram of the Westinghouse 28A controller. K, K are the two hood switches; W, the trolley wheel; and FB, the fuse box; the lightning arrester is not shown; D is the reverse switch; L_1, the No. 1 motor cut-out switch; and L_2, the cut-out switch for the No. 2 motor; $R_4 R_5$ is the small one-part starting coil; and $R_1 R_2 R_3$ the large two-part starting coil; M is the magnetic blow-out coil that goes around the base of the finger board, as shown in Fig. 31; M_1 is the No. 1 motor or the motor through which the current first passes in its passage from the trolley wire to the ground; M_2 is the No. 2 motor or the motor next to the rail or ground.

55. Notes on Car-Wiring Diagram.—In Fig. 38, the cut-out plugs are shown turned so that both motors are cut in, and the dotted lines at L_1 and L_2 are not supposed to represent connections in this position of the cut-out plugs. The path of the current from the trolley wire to the ground on the first notch is W–K–K–FB–T–a–a_1–R_1, along the car wire, as indicated by the arrowhead, to the positive end of the large starting coil at R_1, through the large starting coil and out at R_3, along the R_3 car wire to post R_3 at the left, through the blow-out coil M–X–*13*–*14*–*9*–F_1+–F_1+–F_1+, through the No. 1 motor field, F_1-–F_1-–F_1-–A_1+–A_1+–A_1+, through the No. 1 motor armature, A_1-–A_1-–*15*–*16*, to post R_4; thence on the R_4 car wire to the R_4 post on the positive end of the small starting coil, through this coil and out at R_5 to finger R_5–c_4–c_2–*8*–*6*–b_2–b_3–*7*–*17*–*18*–*12*–*11*–F_2+–F_2+–F_2+, through the No. 2 motor field, out at F_2-–F_2-–F_2-–A_2-–A_2-–A_2-, through the No. 2 motor armature, out at A_2+, directly to the ground wire at G.

56. The two dotted circles in the diagram of the No. 2 motor indicate the fact that the motor is turned end for end, so that its commutator cannot be seen from the same end as can that of the No. 1 motor, whose commutator outline is, therefore, indicated by the full-line circles.

In Fig. 38, only one controller is shown connected up. To connect up the other one, it is only necessary to connect the broken-ended wires in the lower right-hand corner of the

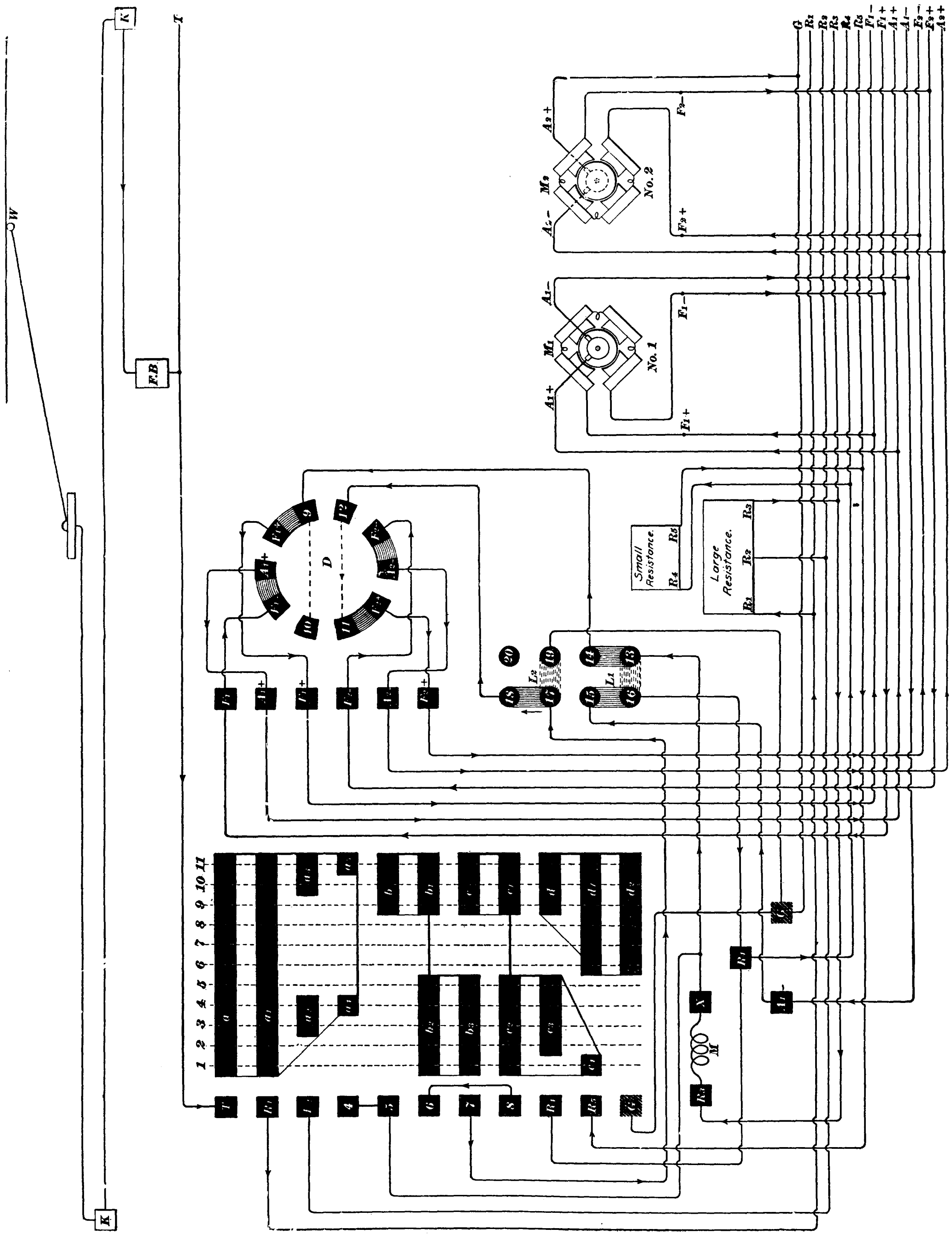


FIG. 38.

sketch to the posts marked the same as these wires are on their ends.

57. Fig. 39 shows the combinations effected by the 28A controller. The fourth and seventh are the running notches. In this controller it will be noted that the resistance is made up into two parts, one of which, R_1 to R_3, is connected, on the first notch, in circuit ahead of the No. 1

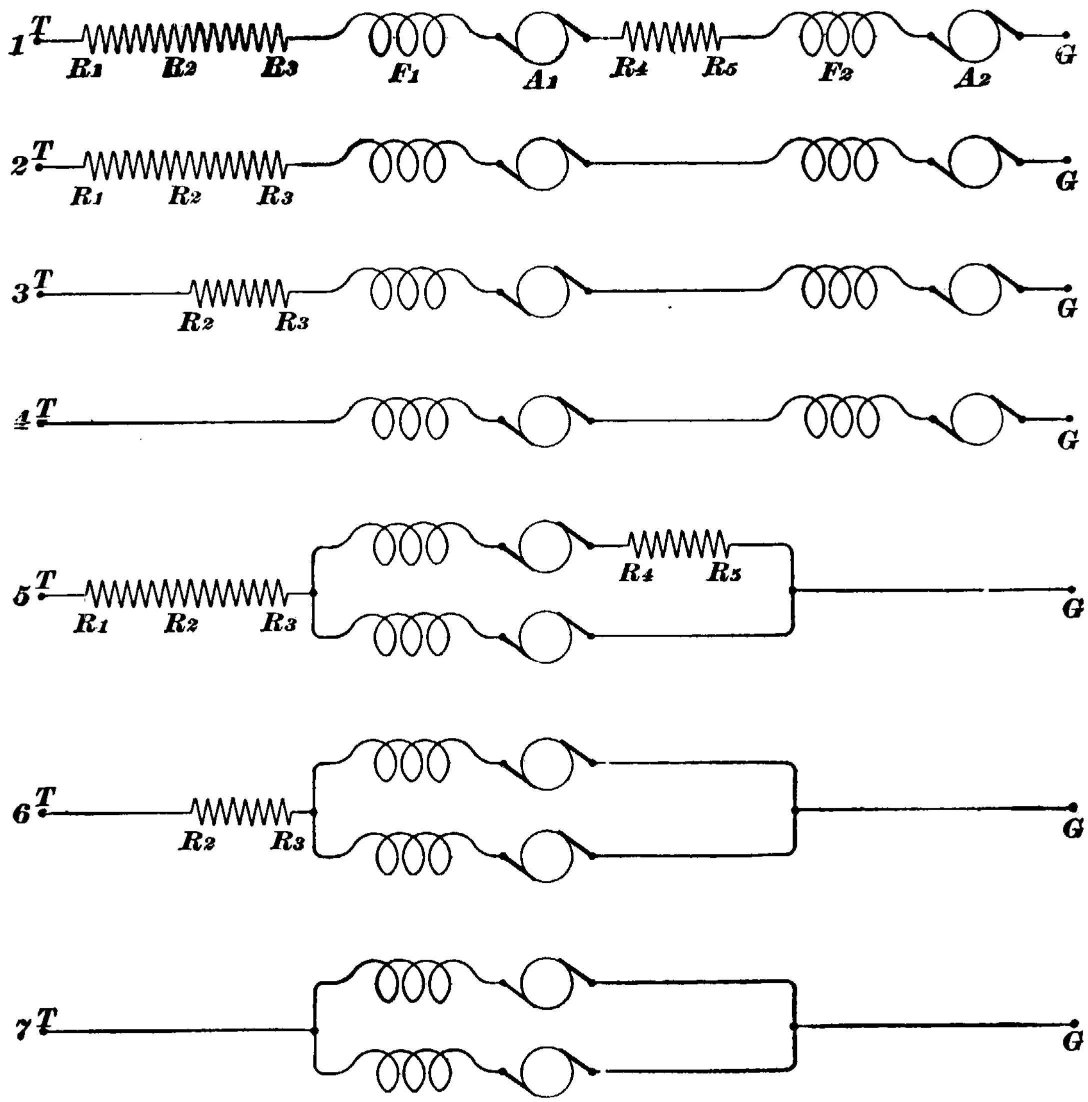


FIG. 39.

motor, and the other smaller part, R_4 to R_5, is connected between the two motors on the first notch. The controller differs in this respect from the General Electric controllers, where the resistance is all in one place. It makes very little difference where the resistance is put so long as it is included somewhere in series with the motors.

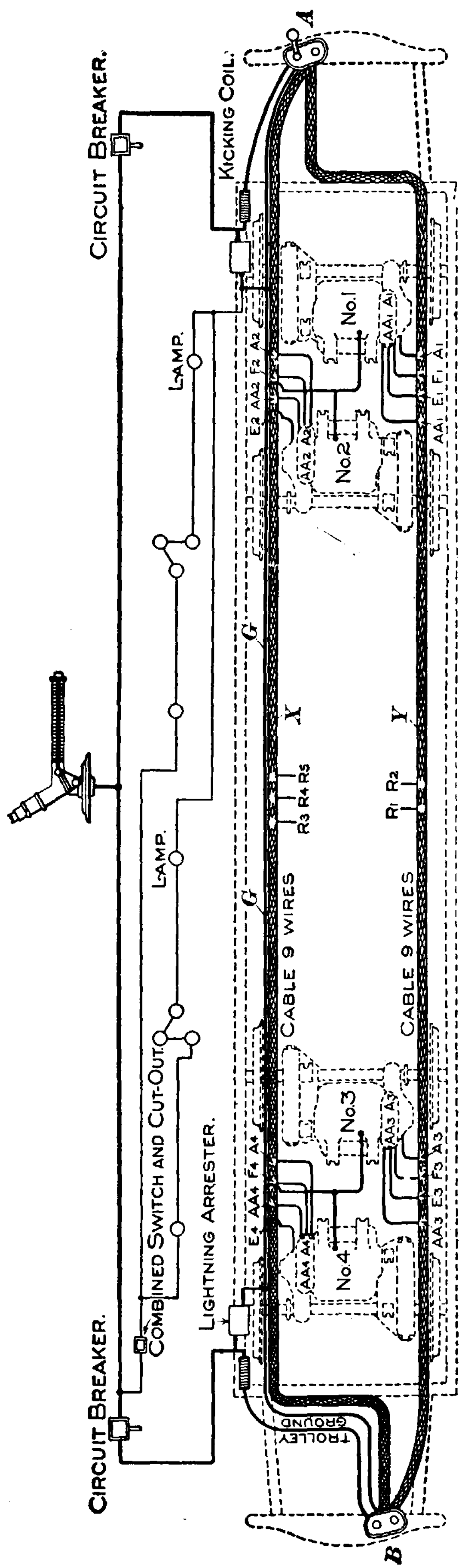


Fig. 40.

FOUR-MOTOR EQUIPMENTS.

58. The general tendency in electric railroading has been towards larger cars and higher speeds. In many cases, the comparatively short single-truck car has given place to the long double-truck car. These long cars may be equipped with either one or two motors on each truck. In some places, maximum-traction trucks, with a single motor on each, are used. In other places, ordinary four-wheeled trucks with a motor mounted on each axle are used. There has been much discussion as to whether four motors of moderate size are as economical as two larger motors. Tests have shown fairly conclusively that the four-motor equipment will use more current than the two-motor equipment under similar conditions; but with four motors, one on each axle, the whole weight of the car rests on the driving wheels, and it has been found that these cars can ascend grades, go through snow, and run on slippery rails, where the two-motor equipment has great difficulty in maintaining its schedule time. This is an important consideration, and four-motor equipments are extensively used notwithstanding the fact that they take more current and are higher in first cost than two-motor equipments. The cost of repairs is also greater with the four-motor equipment.

59. General Arrangement and Method of Control. Fig. 40 shows the general layout of the wiring for a car equipped with four motors and General Electric K12 controllers. The motors, *1*, *2*, *3*, and *4*, are mounted back to back, two on each truck. The resistance coils are mounted under the middle of the car and are connected to the taps R_1, R_2, R_3, R_4, R_5. The two controllers *A* and *B*, the resistance coils, and the motors are connected together by wires run in the cables *X* and *Y*. Each of these cables is made up of nine-stranded rubber-covered wires pulled into canvas hose. *G G* is the ground wire, which is not run in the hose. This ground wire is connected to the frames of all four motors, as shown in the figure. One end of the fields of motors Nos. 2 and 4 is also tapped to the ground wire.

60. The usual method for controlling a four-motor equipment is to connect the motors in pairs in parallel and then to treat the two pairs as if they were single motors, operating them by the series-parallel method, as with a regular two-motor equipment. This will be understood by referring to Fig. 41, which shows the various combinations effected by the K12 controller.

If the student will refer to the description of the K11 controller, he will see that the combinations given in Fig. 41 are practically the same as for the K11, except that here we have four motors in two pairs instead of the two single motors. No. 1 motor is connected in parallel with No. 3, and No. 2 with No. 4, so that a motor on one truck is connected in parallel with a motor on the other (see Fig. 40).

61. The K12 Controller.—The K12 controller used for the operation of four motors is similar in general appearance

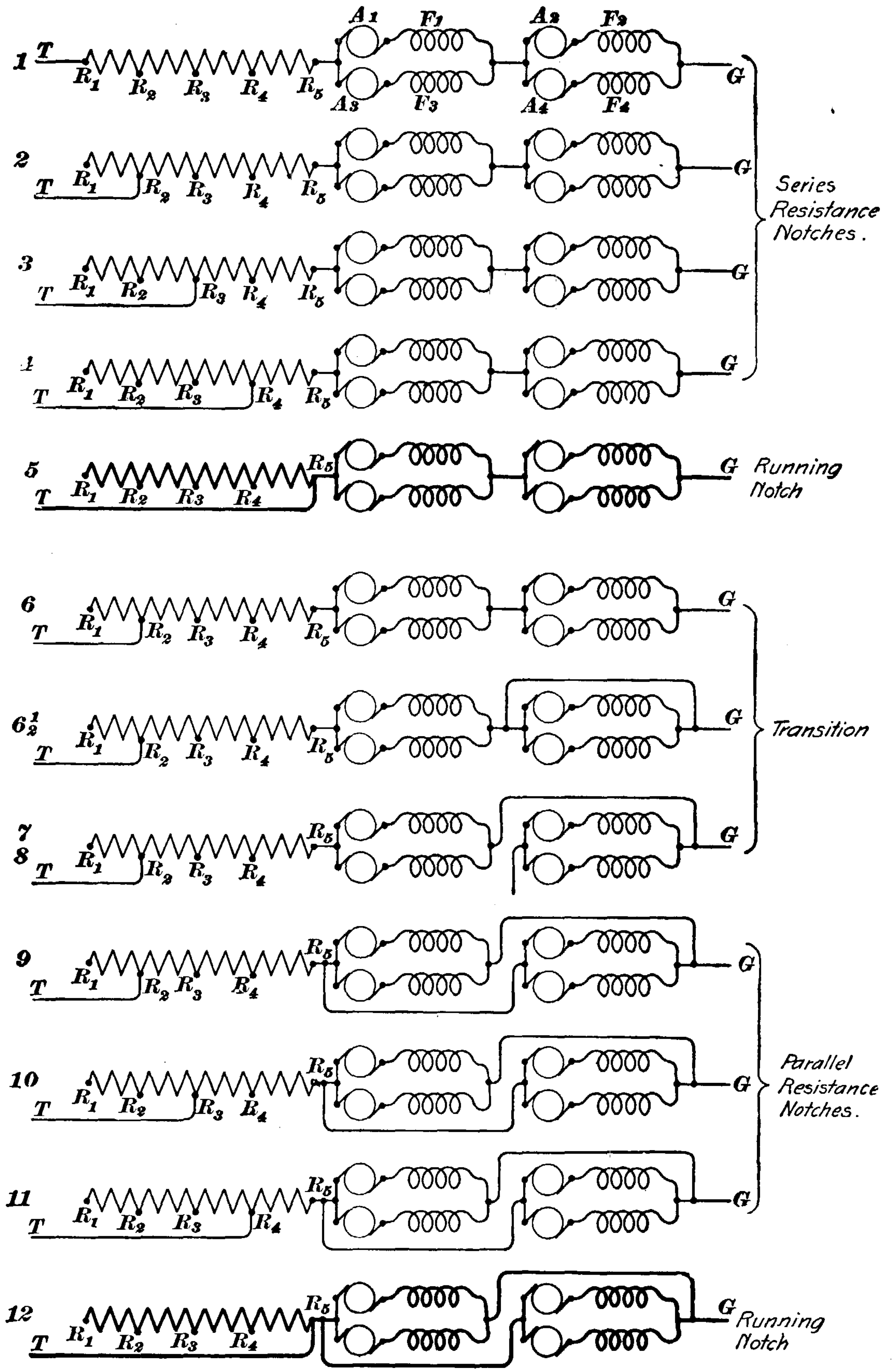
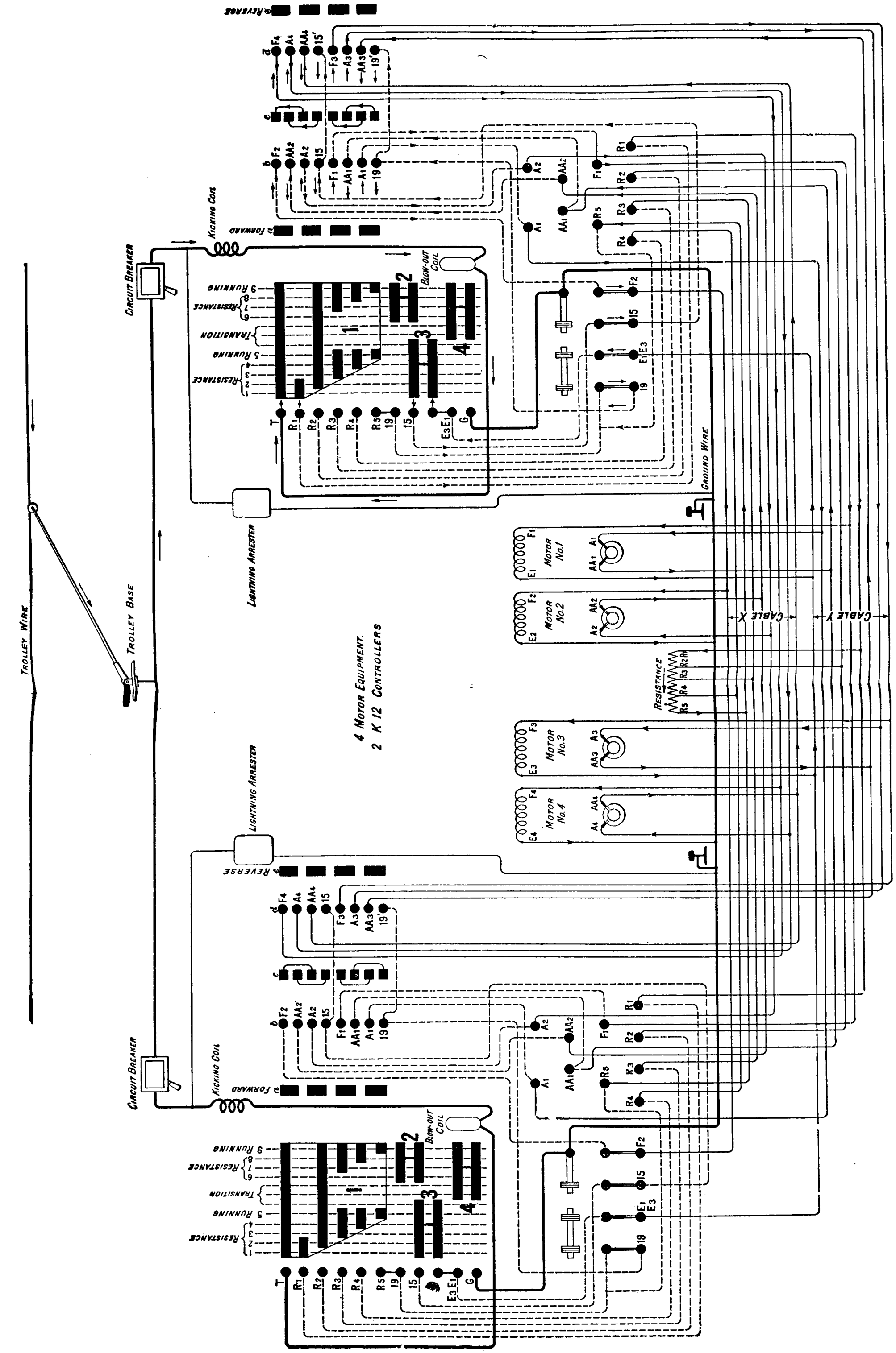

A1
F1
A2
F2
A3
F3
A4
F4
T
R1
R2
R3
R4
R5
G
1
2
3
4
5
6
6½
7
8
9
10
11
12
Series Resistance Notches.
Running Notch
Transition
Parallel Resistance Notches.
Running Notch

FIG. 41.



Trolley Wire
Trolley Base
Circuit Breaker
Kicking Coil
Lightning Arrester
Blow-out Coil
Forward
Reverse
Running
Resistance
Transition
Ground Wire
Motor No.1
Motor No.2
Motor No.3
Motor No.4
Resistance
Cable X
Cable Y
4 Motor Equipment.
2 K 12 Controllers

FIG. 42

to the other type K controllers made by the General Electric Company. Its contact fingers and drum contacts are heavier than the K2 or K10, because the four motors require a large current. The use of the four motors requires some modifications in the construction of the reversing switch, but otherwise the controller is very similar to those just considered.

62. Fig. 42 is a wiring diagram for a car equipped with four motors and two K12 controllers. The power drum is very similar to that of the K10 controller, but a double row of contact fingers is provided on the reverse switch. When the car runs ahead, the reverse-switch fingers *b* are in contact with plates *a* and fingers *d* are in contact with *c*. When the car runs back, fingers *b* make contact with *c* and *d* with *e*, thus reversing the current in all four armatures. The leads E_2 and E_4 from the No. 2 and No. 4 motor fields are permanently connected to the ground wire. The main trolley wire connects to the blow-out coil, as shown. The student by this time should be able to trace out the path of the current on the first notch is indicated by the arrows and is as follows, starting from post T at the power drum: T–R_1–R_1–R_1, through all resistance, –R_5–R_5–19–19–

$$\left\{\begin{matrix} 19-A_1-A_1-A_1-A\,A_1-A\,A_1-A\,A_1-F_1-F_1-F_1-E_1-E_1-E_1-3 \\ 19'-A_3-A_3-A\,A_3-A\,A_3-F_3-F_3-E_3-E_3-E_1-3 \end{matrix}\right\}-$$

$$15-15-\left\{\begin{matrix} 15-A_2-A_2-A_2-A\,A_2-A\,A_2-A\,A_2-F_2-F_2-F_2-E_2 \\ 15'-A_4-A_4-A\,A_4-A\,A_4-F_4-F_4-E_4 \end{matrix}\right\}-$$

Ground.

63. The other combinations are indicated by Fig. 41, and may be easily traced out on the diagram. When the cut-out switches are operated, the motors are cut out in pairs. For example, if something goes wrong with the No. 1 motor and the cut-out switch is thrown up, motors No. 1 and No. 3 are cut out. Four-motor cars require a large current; hence, care must be taken to see that the main wiring has plenty carrying capacity. The student will also notice in Figs. 40 and 42 that the two circuit-breakers are connected in parallel, whereas the hood switches shown on the other diagrams are connected in series. This is the usual practice when circuit-breakers are used. The breaker on the front end is in while the car is running and the one on the rear end is left out, so that only one breaker is in use at the same time. If both breakers were in series, they would both trip in case a short circuit occurred, and the tripping of the one on the rear platform, in close proximity to the passengers standing there, would be undesirable; besides, it might not be convenient to reset the breaker on the back end, because the conductor would very likely be engaged in collecting fares. For these reasons, the breakers are connected in parallel instead of in series.

STREET-RAILWAY MOTORS.

64. A street-railway motor has to meet several conditions not imposed on motors that are used for stationary work. Its design is limited to a large extent by the space in which it is to be placed. It must go wholly beneath the car floor, and its width is limited by the gauge of the track. It must be dust-proof and waterproof, because it may have to run through all kinds of dirt and water. It must be arranged so that it can be readily suspended from the car axle. A railway motor must be substantial in every particular, because it is called on to stand harder usage than almost any other kind of electrical machinery.

As mentioned before, nearly all motors used for railway work are operated by direct current at 500 volts. The fields are connected in series with the armature, because the series-wound motor is capable of giving a strong starting effort and also gives a wide range of speed under varying loads. Moreover, the series-field coils, being wound with a few turns of coarse wire, are substantial and comparatively easy to repair. Alternating-current motors will, no doubt, be