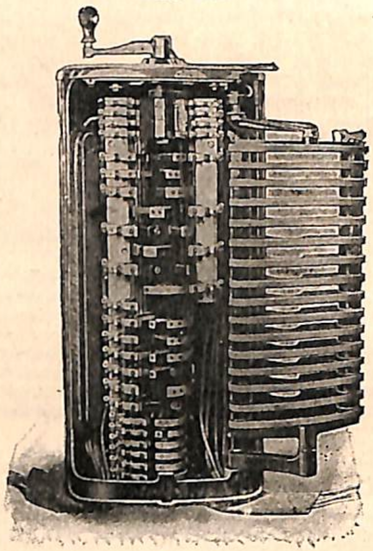
in the number of brake notches makes it more suitable for electric braking than the No. 90. Provision is also made for using the electric brake with one motor cut out.

Westinghouse No. 210 Controller.—The Westinghouse No. 210 controller is shown with arc shield removed in Fig. 40, and is arranged with nine power and seven brake notches.

To reduce sparking at the drum and contact fingers a blow-out magnet is fitted, and is energised by the main current passing through the large coil at the side.

Fig. 41b.



The hinged pole-piece and arc shield are held in position by a catch at the bottom, and can be swung clear when necessary.

The exciting coil of the blow-out magnet is cut out of action on the "full series" and "full parallel" positions to avoid waste of power.

The two small reversing drums are turned round by means of a slotted lever worked from the main spindle.

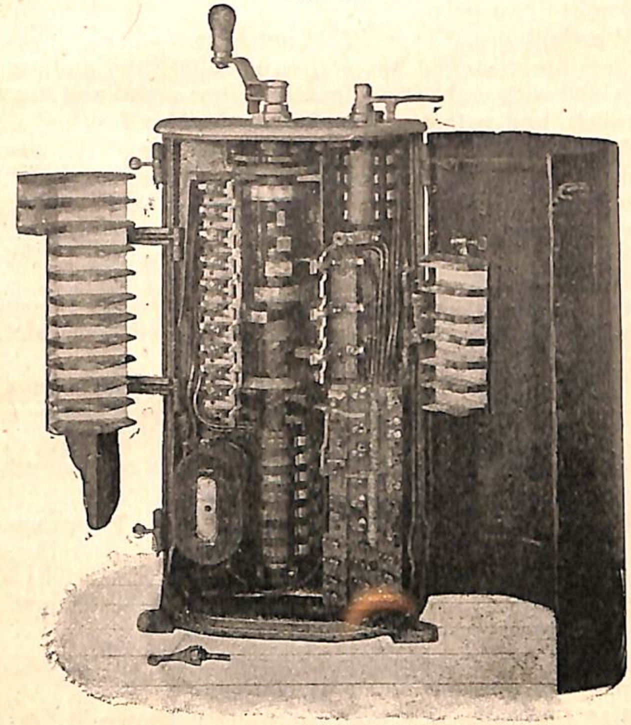
To disconnect a defective motor from service it is necessary to pull forward a small brass knob and turn

one of the small drums to the right, using the small reversing lever for this purpose.

As usual, a catch is provided to prevent the power handle passing full series when running with one motor.

The cables from the line, motors, and rheostat enter at the bottom, and are attached to brass terminals

Fig. 42.



Thomson-Houston B-18 Controller (open).

which are connected to the various "fingers" in the controller.

Connection Diagram.—The complete connections for a controller of this type are given in Fig. 41.

It will be noted that the two bottom fingers are in contact on all brake positions, but must not *both* touch when drum is on power points.

The top finger is in contact on all brake notches, and serves to take the current generated by the motors to "ground," or to the coils of the magnetic brake if such appliance is fitted to the car.

Westinghouse No. 412 Controller.—The Westinghouse No. 412 controller is similar to the No. 210, but is arranged to control "four-motor" equipments instead of two only.

Westinghouse Type T Controllers.—These controllers are designed for motors up to 50-H.P., and are provided with eight power notches (four series and four parallel), and with seven brake notches.

A diagram of the connections of a Type T1 C controller is shown in Fig. 41A, and a controller of this type is shown with cover removed and arc shield withdrawn in Fig. 41B.

A magnetic blow-out is fitted to reduce arcing at the contact fingers.

To cut out of action a defective motor it is necessary to pull back fingers + 1 or + 2 on reverse drum and finger F1+ or F2+ on main drum.

The diagram shows connections arranged for magnetic braking which is not interfered with when a defective motor is cut out.

For rheostatic braking it is necessary to connect together fingers B and G on main drum.

Thomson-Houston Controllers. — The Thomson-Houston Co. manufacture several types of series-parallel controllers for tramway work.

Some of these are arranged for electric braking, and are termed "Type B."

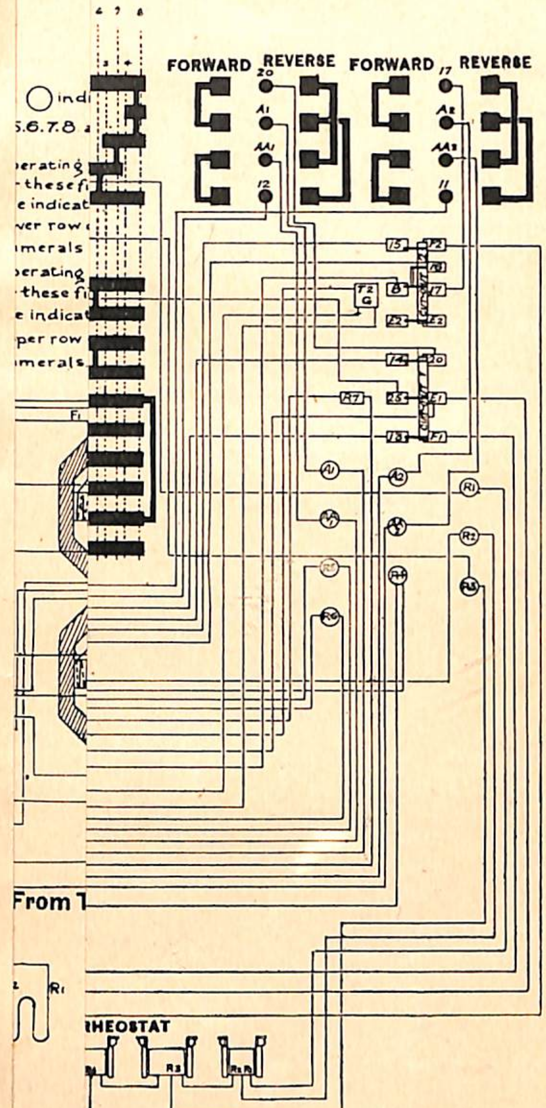
Others are arranged with only an "emergency stop" position, and are called "Type K."

B-18 Controller.—A B-18 controller is shown in Fig. 42, and is capable of controlling two 30-H.P. motors.

Eight **power** and six **brake** notches are provided, and as usual with T.H controllers a "blow-out" magnet is fitted to reduce arcing at the contacts.

The controller is depicted with the hinged shields pulled forward, and the magnet coil can be noticed at the lower left-hand corner.

An interlocking catch is fitted to prevent wrong manipulation of the controller, and a notched wheel at the



CONNECTIONS.

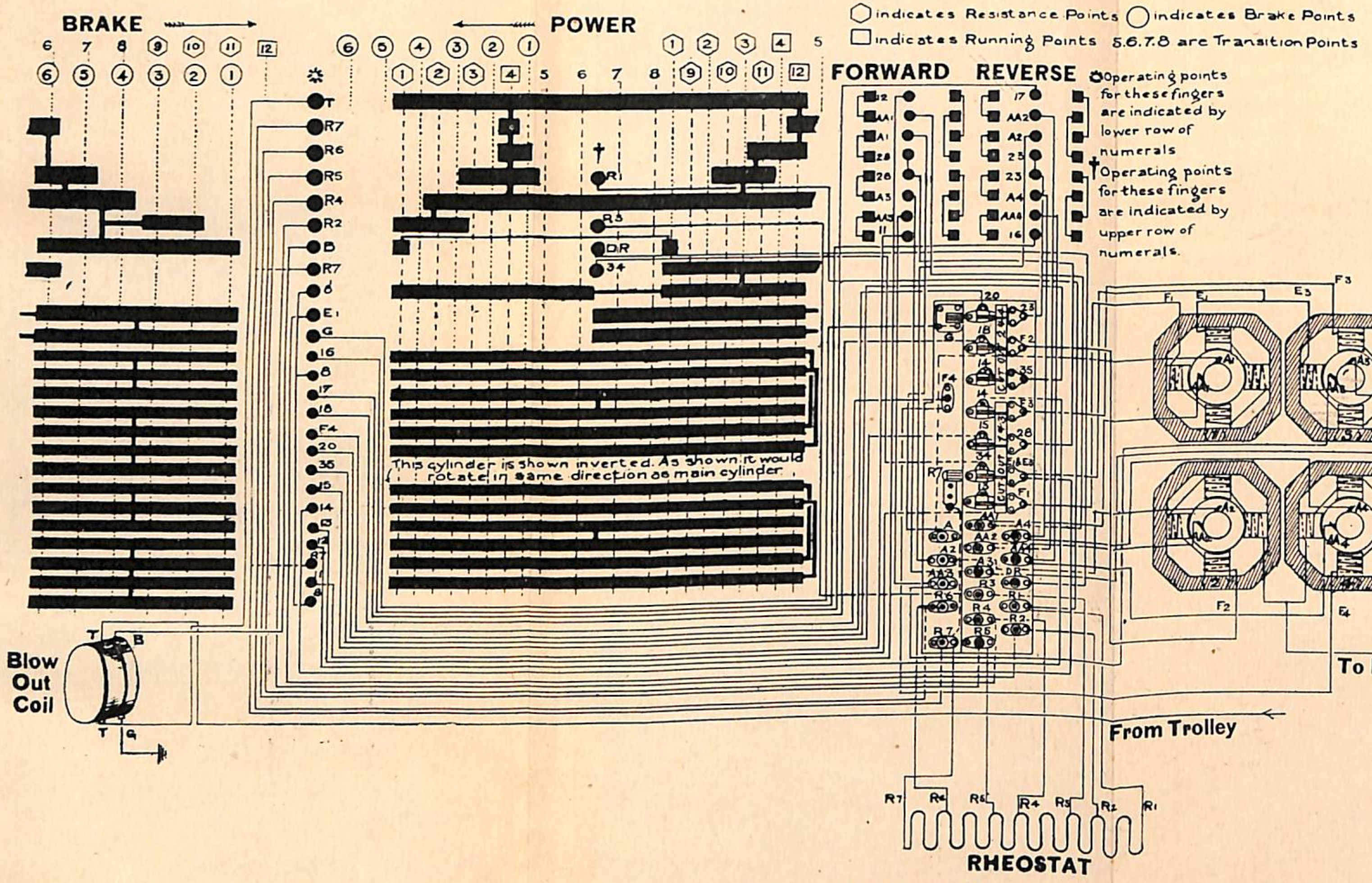


Fig. 44.—Diagram of Connections of B-6 Controller.

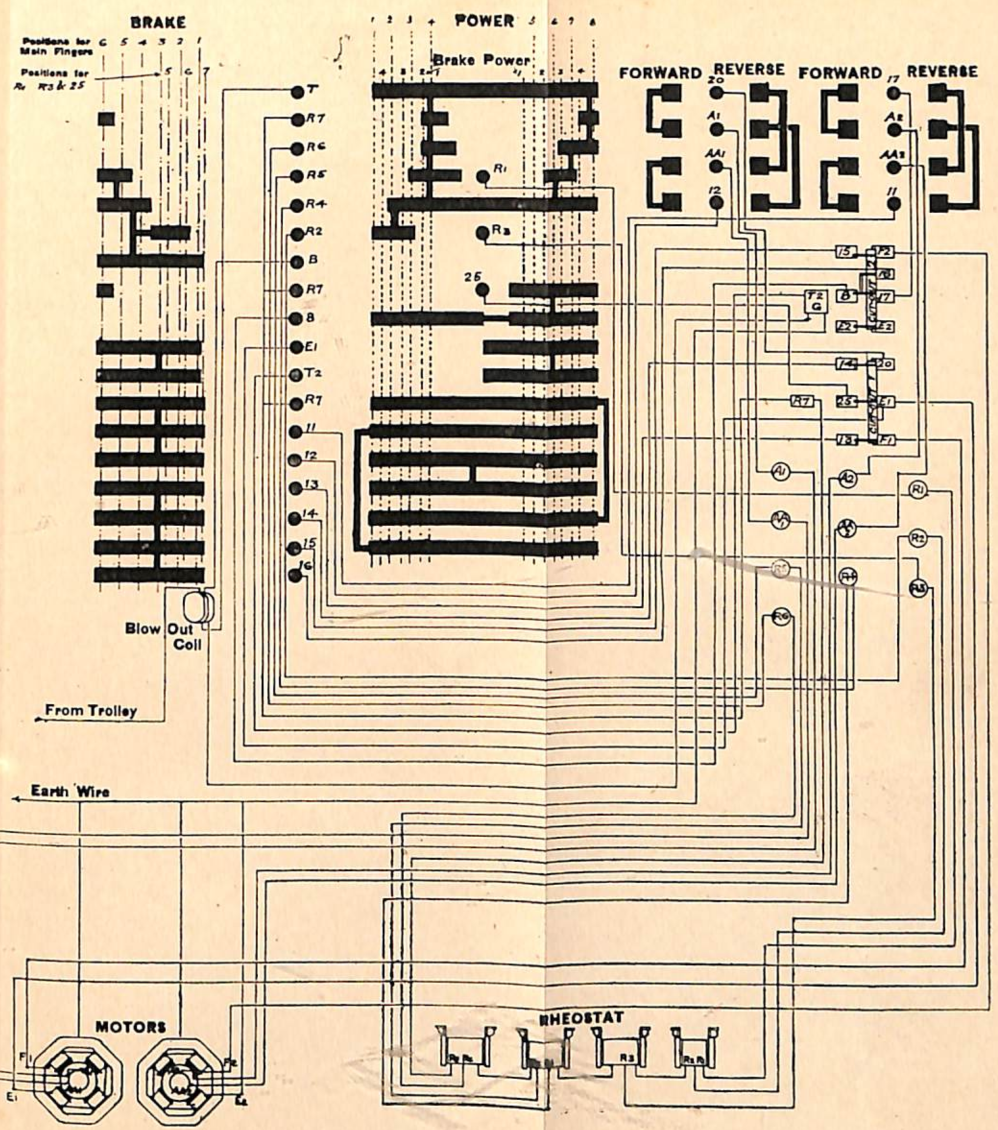


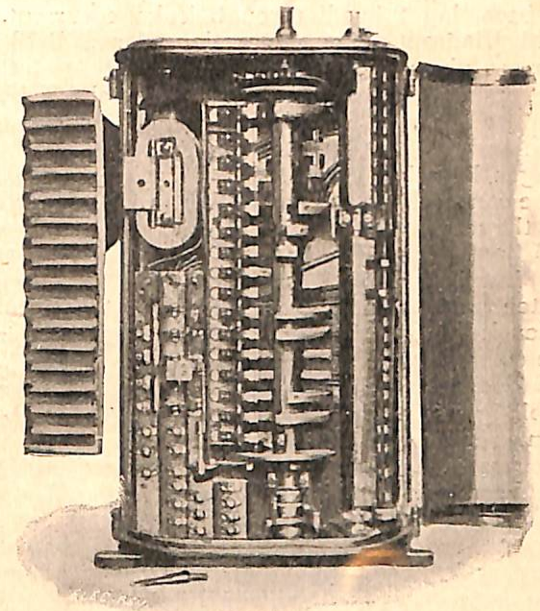
Fig. 43.—B-18 Controller Connections.

top of the main drum with roller pawl serves to hold the controller handle steady at the different positions.

The main drum makes contact when turned with spring "fingers" arranged at both sides, and at the bottom of the main spindle a smaller drum is fitted and makes contact with side fingers also.

The reversing handle serves to turn the small contact

FIG. 45.



THOMSON-HOUSTON B-13 CONTROLLER

drum directly under the top cover, and changes the armature connections to allow of the car running backward when necessary.

To allow of a defective motor being switched out of circuit, two small switches are fitted at the right-hand side; by moving one of these switches over to the left the corresponding motor is cut out, and the car runs on the remaining good one.

When a "cut-out switch" is pulled over, a brass rocking bar is tilted to the side and prevents the controller handle from being moved past half power.

The supply cable (T) is attached to a terminal on the "blow-out" coil, and the other cables are connected to the terminals at the other side, and are all plainly lettered for identification.

When the car is running on a single trolley system the outer case of the controller is connected by a brass screw to the ground terminal (G) to prevent the case from becoming "live" through leakage current.

B-18 Diagram.—The connections for a B-18 controller are given in Fig. 43.

Fingers R1 and R3 are used on the 1st and 3rd brake notches, and finger 25 is in contact only on the series points.

Finger B makes contact on all brake notches, and may be connected to "ground" for rheostatic braking, or to the magnet coils if magnetic brakes are used.

B-3 Controller.—The B-3 controller is similar to the B-18, but is arranged for use with the Thomson-Houston magnetic disc brakes, and on the 1st power position it permits trolley current to pass through the brake coils to make them slack off.

B-6 Controller.—The B-6 controller is arranged for controlling cars fitted with four motors, and in general design is similar to the B-18 except for some slight differences at the terminal board and reverse drum.

As the motors are connected in "pairs," moving over one of the cut-out switches disconnects two motors and leaves the other two to propel the car.

The connections made by this controller on the power and brake notches are given in Fig. 44.

B-13 Controller.—The B-13 controller is arranged with nine power and seven brake points, and is suitable for use with magnetic disc brakes.

The main drum is of the usual construction; a smaller one is fitted at the side and is turned into contact when the main spindle is brought round.

The reverse drum is worked direct by the small handle of the controller as usual, and is "interlocked" with the power drum.

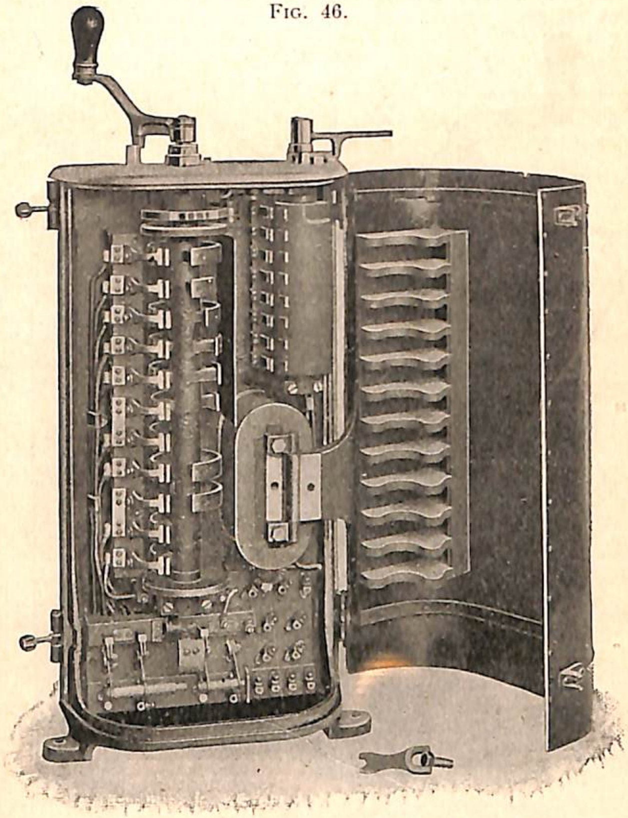
The terminal board is fixed at the left of the case, and immediately above are fitted the motor cut-out switches.

In Fig. 45 a B-13 controller is shown open.

Type "K" Controllers.—The Thomson-Houston Type "K" controllers are not arranged for electric braking, but provision is made for an emergency stop by short circuiting the car motors.

This is effected by throwing the reversing handle

Fig. 46.



Thomson-Houston K-10 Controller.

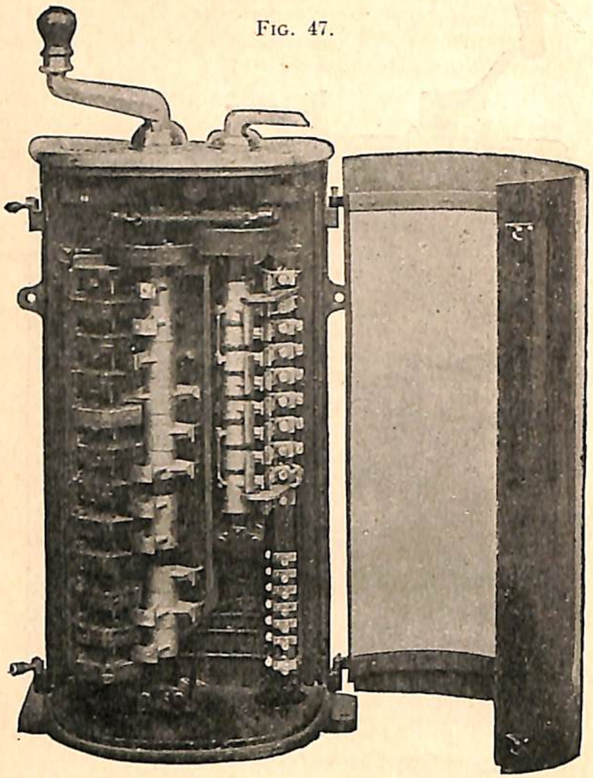
past the usual positions, and a small catch locks it in either of the "emergency" points until intentionally released after the car stops.

K-10 Controller.—A K-10 controller is shown in Fig. 46, where it will be seen that the usual construction is followed, except that the terminal board and motor cut-outs are somewhat differently placed.

Nine power and seven brake notches are provided, and a magnetic blow-out is fitted to reduce arcing at the fingers and drum contacts.

K-9 and K11 Controllers.—The K-9 and K-11 con-

FIG. 47.



BRUSH CO'S H-2 CONTROLLER (OPEN).

trollers are similar to the K-10, except that the K-9 is arranged for double trolley or conduit lines, and the K-11 is for two 50-H.P. motors.

K-12 Controller.—The K-12 controller is arranged for four-motor equipments, and in general design is similar to the K-11 class.

K-2 and K-1 Controllers.—The K-2 and K-1 controllers have nine power notches, and have **four** points where the rheostat is cut out of action.

On the 4th notch the motors are in series without resistance, and on the 5th the current through the field-magnet coils is reduced by a "shunt," and the car runs a little faster.

On the 8th notch the motors are in parallel with all resistance cut out, and on the 9th notch the field-magnets are again "shunted," and the speed increased thereby.

FIG. 48.

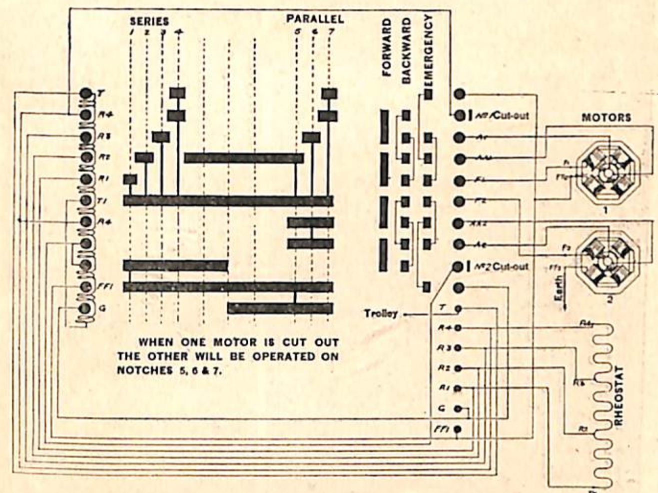


DIAGRAM OF BRUSH H-2 CONTROLLER.

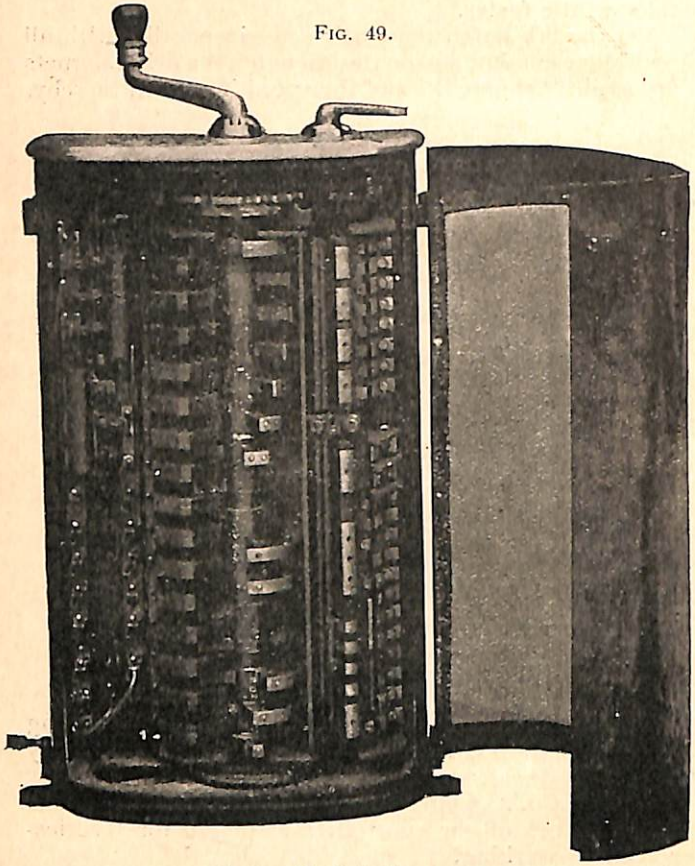
The 5th and 9th notches are suitable for fast running on the level, but should not be employed on heavy grades or where a strong pull is required.

Brush Co.'s Controllers.—The Brush Co. make several types of car controllers arranged for "series-parallel" working.

H-2 Type.—The H-2 is shown in Fig. 47; it has seven power notches (four series and three parallel), and the reverse handle may be moved to an "emergency stop" position, when the motors are short circuited, and act as a powerful brake.

H-3 and H-4 Types.—The Brush H-3 and H-4 controllers are similar to the H-2 in general construction, except that the H-3 is arranged to " shunt " the field coils of the motors on the last notch for fast running, and the H-4 is for four-motor equipments.

Fig. 49.



Brush H. D-2 Controller.

H. G.-2 Controller .—The H. G.-2 controller is like the H-2 on the power side, but the reverse lever has one position for connecting the motors so that they act as generators and feed back current into the line when

the car is descending long steep grades, thus acting as an economical type of electric brake.

To reduce arcing at the contacts, blow-out coils or " solenoids " are fitted between the fingers, and the

Fig. 50.

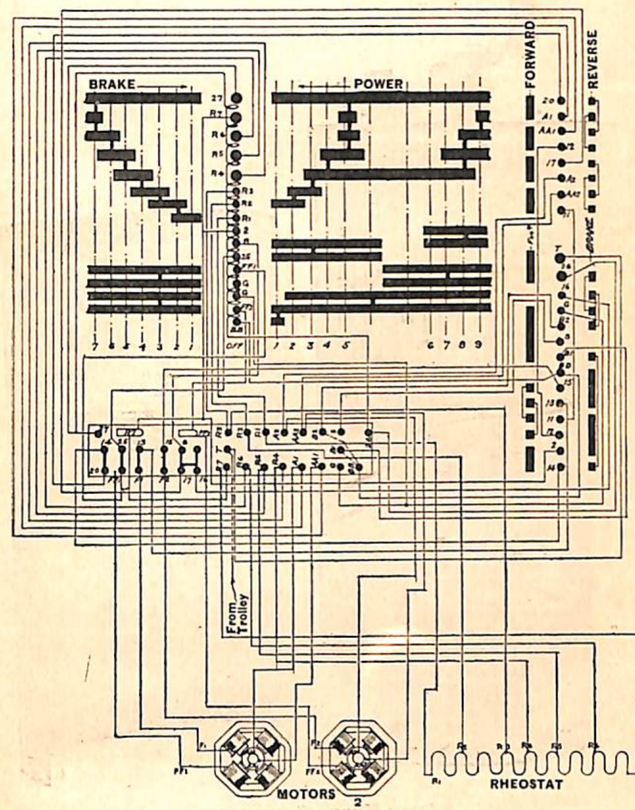


Diagram of Brush H. D-2 Controller.

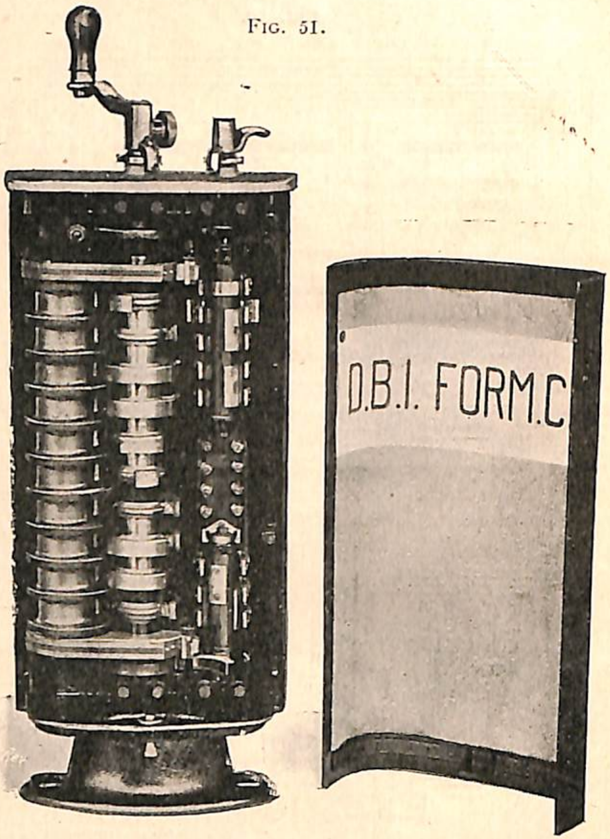
main current passes through these to produce the necessary magnetic effect.

On the " running " notches the solenoids are cut out of action.

To cut out a defective motor it is necessary to pull back one of the fingers at the side of the reverse drum, and the remaining good motor is then operated on the *parallel notches* only.

H-2 Diagram.—A diagram of the connections for an

Fig. 51.



Dick-Kerr Controller.

H-2 controller is given in Fig. 48, and is typical of the other forms mentioned.

H. D.-2 Controller.—The H. D.-2 controller has nine power and seven brake points, and is illustrated in Fig. 49.

Fig. 52.

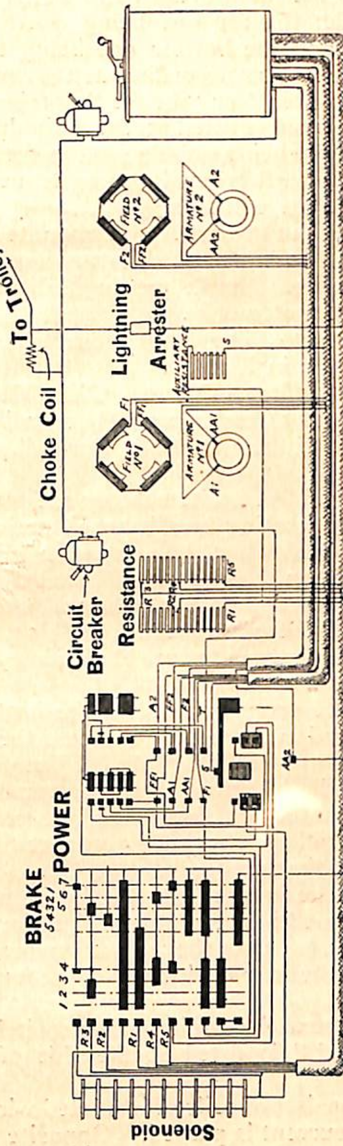


Diagram of Dick-Kerr Controller.

In addition to the main drum two smaller drums are fitted at the side; the top one being operated by the reverse handle, and the bottom one being turned into contact with side fingers according as the main drum is moved to the "power" or "brake" notches.

A blow-out solenoid is fitted at the main drum fingers to prevent arcing when switching off power, and this can be pulled forward when it becomes necessary to clean or examine the contacts.

The motor cut-out switches are mounted over the terminal board at the left-hand side, and a catch is fitted to prevent the power handle passing full series when running with one motor only.

H. D.-2 Diagram.—The connections for an H. D.-2 controller are given in Fig. 50.

Dick-Kerr Controllers.—Messrs. Dick, Kerr and Co. supply several types of series-parallel controllers.

In Fig. 51 one of their D. B.-1, Form C. controllers is shown open.

Seven power and five brake notches are provided.

As usual, the operating handles are interlocked, and can only be removed when the controller is brought to the "off" position. The small handle turns the contact drum directly underneath and controls the direction in which the car travels.

The large handle serves to turn the main cylinder into contact with the side fingers.

A small contact drum is fitted at the bottom of the large cylinder, and is turned round when the controller is moved to the "power" or "brake" notches.

When the handle is moved to the power notches the small drum at the bottom is turned into contact with side fingers, and allows the trolley current to reach the motors to propel the car.

When the handle is moved to the brake notches the small drum is turned in the contrary direction, and connects the motors, so that they act as generators, and serve to stop the car quickly when found necessary.

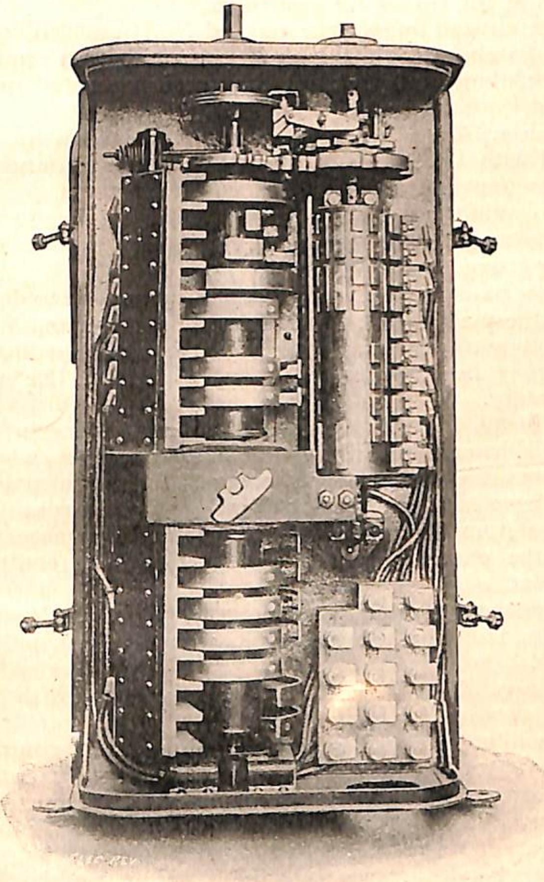
To prevent destructive arcing when switching off, a "magnetic shield" is fitted at the side of the main contact drum.

This device consists of coils of insulated wire, through which the main current is passed. Opposite the fingers

are fitted copper bobbins, each bobbin being separated from its neighbour by insulating fireproof partitions.

The action of the device is to attract the arcs which

FIG. 53.



WITTING-EBORALL CONTROLLER.

occur at the fingers and cylinder contacts to the copper bobbins, and extinguish them before they can cause damage by burning.

The coils in the magnetic shield are cut out of action at full-series and full-parallel, to avoid waste.

To cut out a defective motor it is necessary to pull back one of the fingers at the side of the small reverse drum at the top of the controller.

The cut-out fingers are marked No. 1 and No. 2, and have catches provided to hold them off when required. When a motor is cut out the car is operated on the parallel notches only.

In Fig. 52 is given a diagram of connections for a car fitted with Type D. B.-1, Form C, controllers, arranged for use on the trolley system, with rail return.

In conduit systems the current, after passing through the motors, returns to the power station by one of the underground conductors.

Two main switches are fitted on the car, one to disconnect the positive cable from the collecting plough, and the other to disconnect the negative cable, so that the car may be completely cut off from the line when necessary.

Witting, Eborall and Co.—The controllers supplied by this firm are all built on much the same lines, whether for operating two or four motors. The main point of difference between the controllers for two motors and for four motors lies in the different connections necessary, and the extra number of positions of the controller cylinder.

For four motors, in the series positions, each pair of motors is connected in parallel, and the two pairs in series.

In Fig. 53 an E. H.-9 controller is shown with outer cover removed.

It will be sufficient to describe the standard controller E. H.-10 for two motors. The necessary connections are made by two movable cylinders, one large and one small.

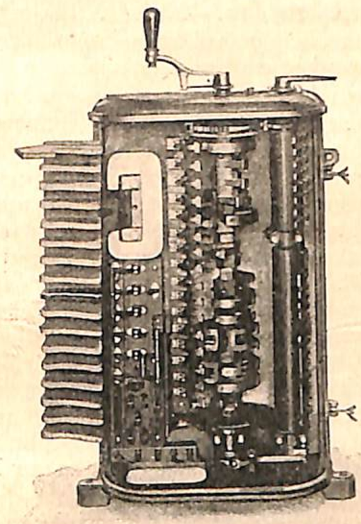
The small cylinder is arranged to control the direction of rotation of the two motors, or of either of them, while the large cylinder controls the starting, running, and braking.

The two cylinders are connected by an interlocking gear arranged so that it is impossible to reverse when current is on the motors. Further, it is impossible to move the large cylinder unless the small cylinder is in one of its working positions.

The reversing cylinder has six positions to which it can be moved by hand, and the following connections can be made by means of it, the two motors being denoted by A and B respectively.

1. Motor A and Motor B . . .	Forwards.
2. ,, ,, . . .	Backwards.
3. Motor A alone . . .	Forwards.
4. Motor A alone . . .	Backwards.
5. Motor B alone . . .	Forwards.
6. ,, ,, ...	Backwards.

Fig. 54.



Bruce Peebles Controller.

Thus by means of this cylinder either motor can be used alone, and no separate motor cut-outs are required.

Connections made.—The controlling cylinder allows the following connections to be made :—

1st	power notch.	Motors	in series.	Rheostat	in action,	R 2.
2nd	,, ,,	,,	,,	,,	,,	R 3.
3rd	,, ,,	,,	,,	,,	,,	R 4.
*4th	,, ,,	,,	,,	,,	cut out,	R 5.
5th	,, ,,	Motors	in parallel.	,,	in action,	R 3.
6th	,, ,,	,,	,,	,,	,,	R 4.
*7th	,, ,,	,,	,,	,,	cut out,	R 5.

* Running points.

1st brake notch.	Motors in parallel.	Rheostat in action,	R 1.
2nd ,, ,,	,, ,,	,, ,,	R 2.
3rd ,, ,,	,, ,,	,, ,,	R 3.
4th ,, ,,	,, ,,	,, ,,	R 4.
5th ,, ,,	,, ,,	,, cut out,	R 5.

Should either of the motors be cut out by the reversing cylinder, the controlling cylinder makes the above connections with the remaining motor.

When running with one motor alone, the controller cannot be taken past the full-series notch.

Bruce Peebles Controller.—Messrs. Bruce Peebles and Co.'s series-parallel controller is shown open in Fig. 54. Nine power and seven brake notches are provided.

The main drum when turned moves, by gearing, the small drum at the side, and establishes the proper connections for "running" and "braking."

The small drum at the top serves to reverse the motors, and is interlocked with the main drum.

A magnetic blow-out is fitted to reduce arcing, and two motor cut-out switches are mounted immediately over the terminal board on the right.

The connections of this controller are similar to the Brush H. D.-2 controller (Fig. 50).

Regenerative Control.—Instead of employing series wound motors with a rheostat in the main circuit to control the flow of current when starting and accelerating, it is practicable to use motors having shunt wound field magnets, and to vary the speed of the car by varying the strength of the field magnets.

With shunt wound motors it is possible to use the motors to brake the car electrically and return to the overhead line some of the current thus generated, instead of wasting it in the rheostat as is done with the ordinary electric brake and series wound motors.

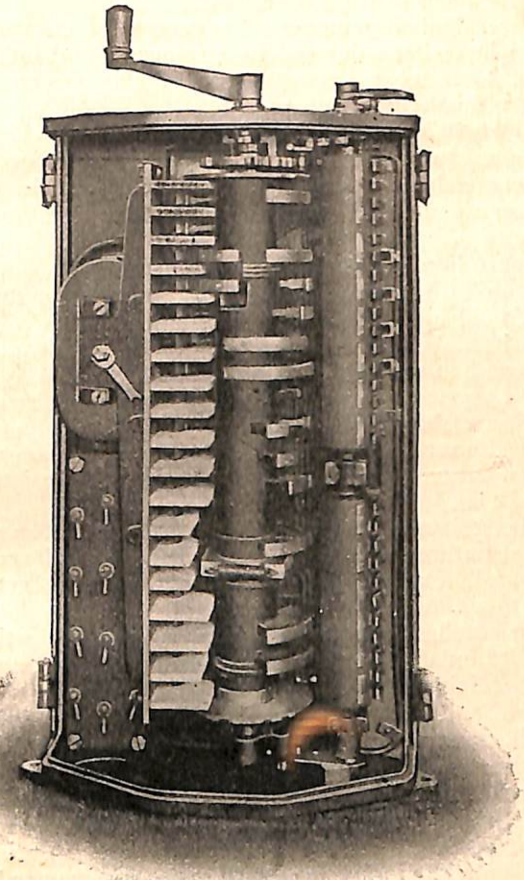
The usual arrangement for regenerative control is first to excite the field magnets of the car motors to their full strength and then admit the current to the armatures through a small main rheostat. Under these conditions the car runs at its lowest speed.

By altering the strength of the field magnet current the speed of the motor can be increased to the maximum, or varied according to requirements.

An auxiliary rheostat is used to vary the strength of the shunt current.

As the shunt wound motor will try to run at a constant speed up hill or down hill, according to the strength of its field magnets, it will be understood that when it

Fig. 55.



Raworth's Controller.

becomes needful to reduce the speed of the car, or descend inclines, it is merely necessary to increase the strength of the shunt current and the motors will automatically retard the car or check its speed down the hill.

The work done in retarding the car is absorbed in driving round the motor armatures, and the motors being driven in this fashion act as generators and feed current back into the line.

Several arrangements of regenerative control apparatus have been devised by engineers, and indications point to a more extended use of this system of car control in the near future.

Raworth's Series Parallel Controllers.—These are designed to secure the advantages of working the car motors either in series or in parallel, and in general design are similar to ordinary controllers used for series motors.

Controller No. R 6 is shown open in Fig. 55, and is arranged for twelve power and regenerative notches, of which six are running notches.

It has also three rheostatic brake notches, and is designed to control two 30-H.P. motors.

The connections established by this controller on each notch are shown in Fig. 56.

The shunt field circuit is first closed, then on notch 1 the armatures are connected in series with resistance in circuit.

The resistance is gradually cut out, so that on notch 4 the armatures are acted on by full line voltage, with fields fully excited, and the car runs at from three and a half to six miles per hour.

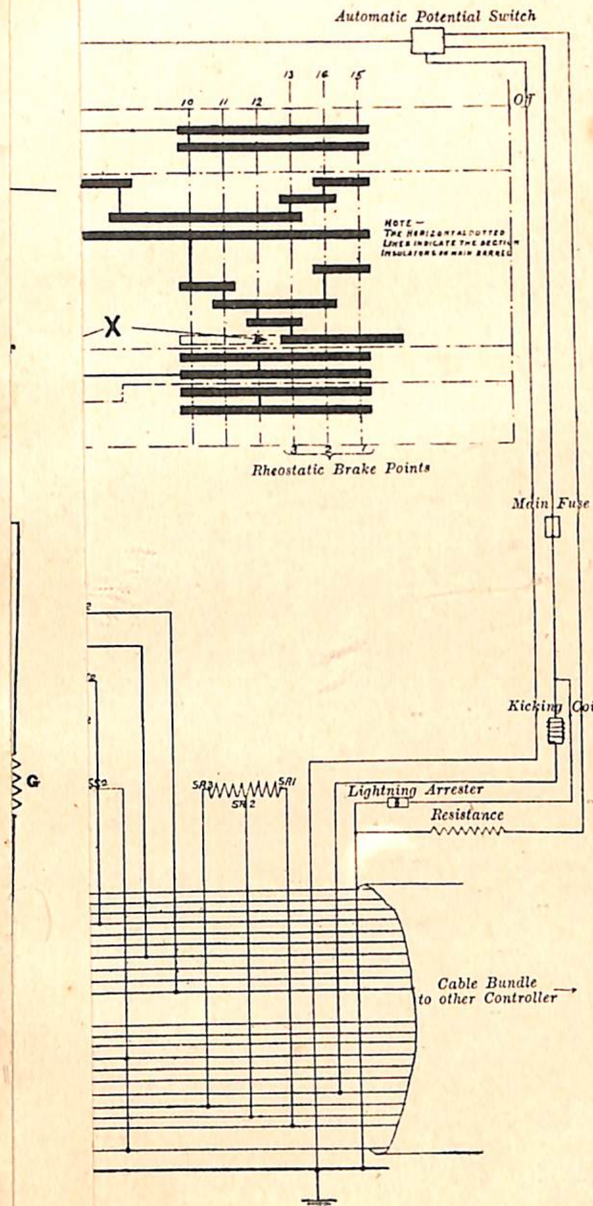
On notches 5 and 6 resistance is inserted in the field circuit, and causes the motors to run faster owing to the weaker field produced.

Continuing in the same direction with the controller handle on notches 7, 8, and 9 the connections established are the same as on 6th notch.

On 10th notch the resistance in the field circuit is cut out, thus giving maximum field strength, and the armatures are connected in parallel, each in series with a series field winding and with resistance inserted in the main circuit.

A resistance is put in parallel with the series windings, so that only so much current as is necessary to balance the load between the two armatures passes through the series windings.

On notches 11 and 12 the main resistance is cut out in



ER.

Fig. 56.

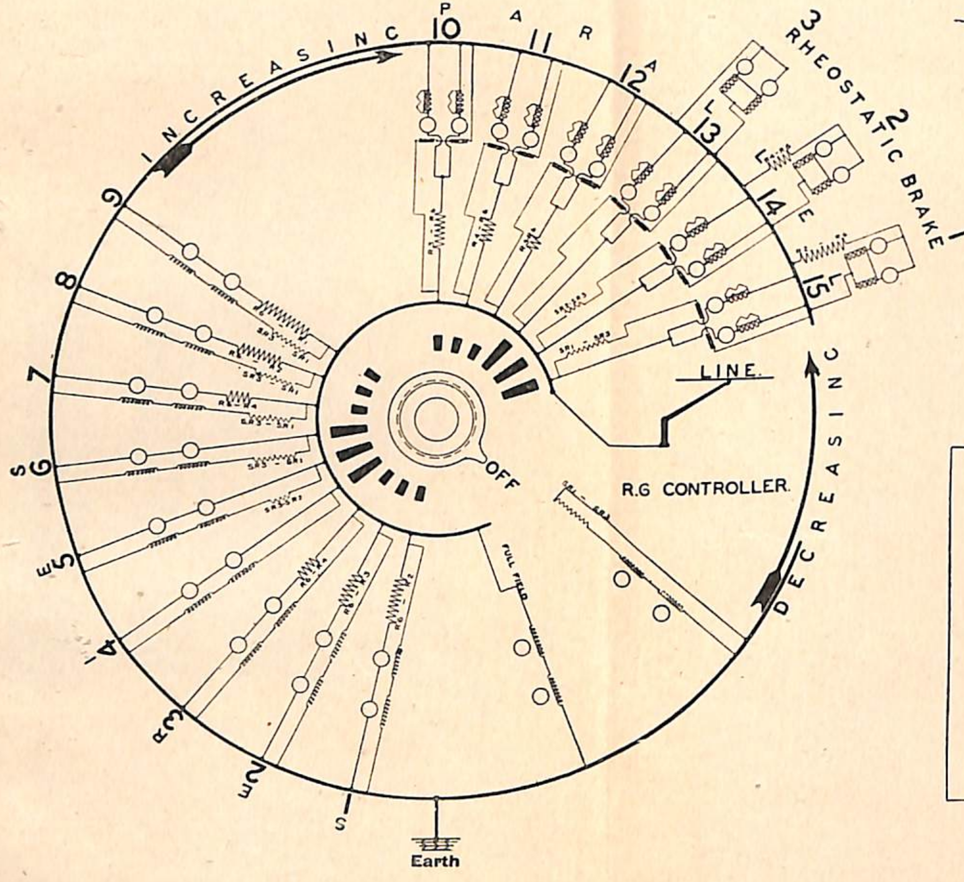


Fig. 58.

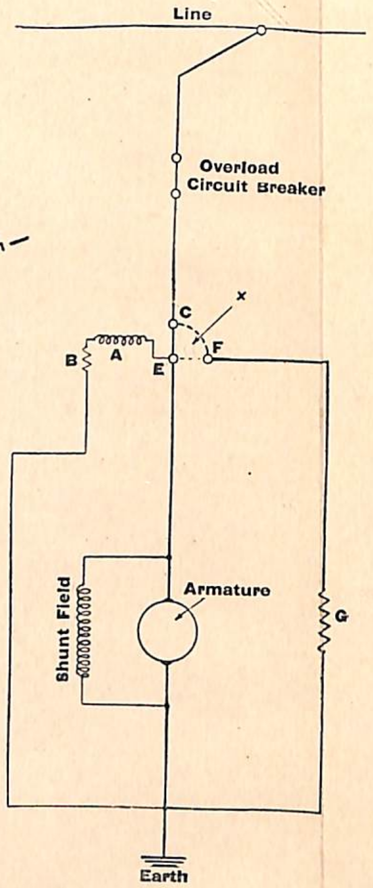


Fig. 57.

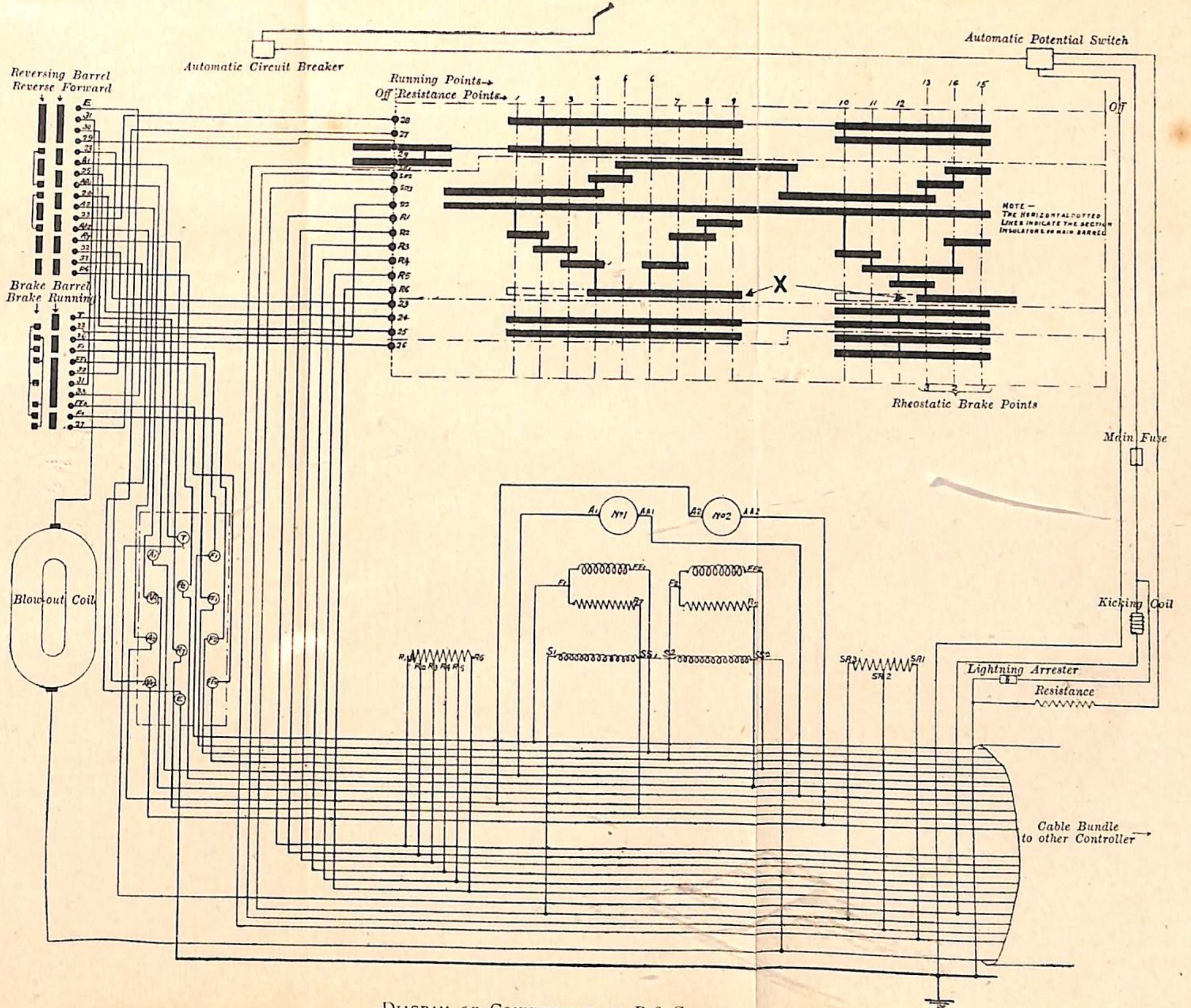


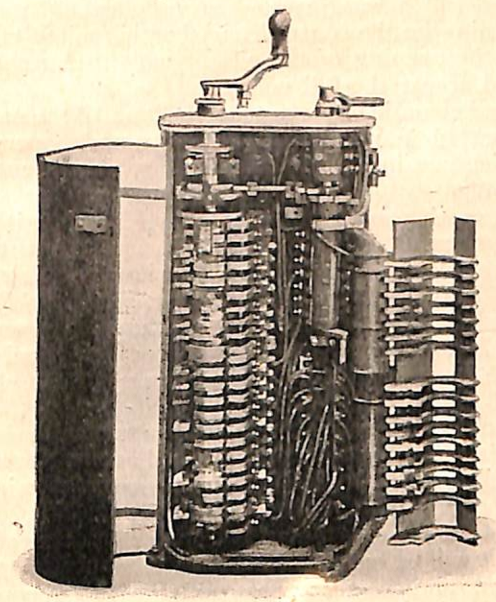
Diagram of Connections of R 6 Controller.

steps, and on notch 13 the armatures are in parallel and acted on by full line voltage, and field strength is at maximum.

On notches 14 and 15 the field strength is weakened by introduction of resistance, and the car speeds up to the maximum rate.

When the controller handle is moved back the same combinations are made as far as notch 13 as when

FIG. 59.



PLATFORM CONTROLLER.

moving forward, and the speed of the motors reduced by increasing the field strength.

Continuing backwards the connections made on notches 12, 11, and 10 remain as on 13, and when the circuit is opened preparatory to going into series there is no resistance in the armature circuit.

On notch 9 resistance is connected in series with the fields and the armatures are in series with resistance in main circuit.

On notches 8 and 7 the main resistance is cut out by steps, and on notch 6 the armatures are in series across the full line voltage.

On notch 5 the resistance in series with the motor fields is reduced, and on notch 4 it is cut out altogether.

At this notch the speed of the car has been reduced to the lowest regenerating speed.

To stop the car the controller is moved to "off" position and the hand-brake applied.

When moving from notch 4 to "off" position the resistance which was inserted on notches 1, 2, and 3 when turning on the controller is short-circuited to provide for the opening of the circuit with the armatures connected across the full voltage.

On the rheostatic brake notches 1, 2, and 3 the motors are connected in parallel as series wound generators with resistance in the main circuit, which is cut out step by step.

The three rheostatic brake notches coincide with the power notches 15, 14, and 13, and the arrangements for this are as follows: As mentioned previously, on notches 1, 2, & 3, and 10, 11, & 12 the connections established when feeding up the controller are as shown on the diagram, but when the handle is moved backwards the resistance in series with the armatures is kept short-circuited.

On notches 7, 8, and 9, when the controller is moving backwards the connections established are as shown in diagram, but when moving forward the resistance in the armature circuit is kept short-circuited.

Referring to the diagram of R 6 controller connections (Fig. 57) it will be seen that finger 22 is connected to the trolley lead, and the six fingers underneath are connected to the main resistance used in the armature circuit.

When the controller drum connects the trolley finger 22 to one of the resistance fingers the current flows through the resistance connected between that finger and the bottom finger R 6, and then through the motor armatures.

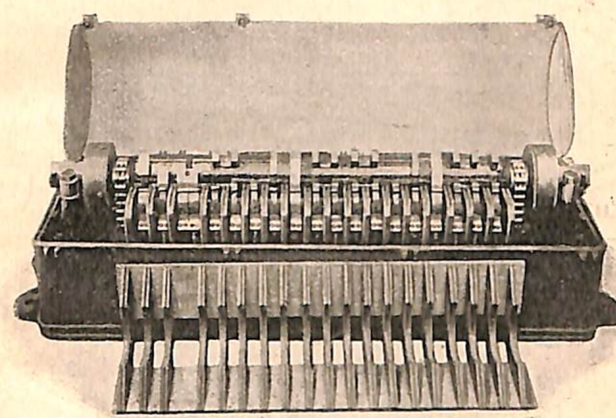
Contact ring X is loose on the main drum, and is driven by a pin working in a slot, which permits the loose ring to lag behind the main drum by the space covered by three notches. The position of the loose ring, as shown on the diagram, represents its position

when the controller is moving forward, but if the handle is moved, say, to notch 6, and then back to off position, the slack ring hangs back to position shown in dotted lines.

By doing this the resistance in circuit on notches 1, 2, 3, 10, 11, and 12 is short-circuited when moving backwards, and on notches 7, 8, and 9 is short-circuited only when the power handle is moving forward.

As stated, notches 15, 14, and 13 are rheostatic braking notches when the controller is turned past the off position.

Fig. 60.



Field-Changer.

When the finger 22 is disconnected from trolley and connected to "earth," and the motor series field coils are reversed by the small cylinder on the left of the diagram, the resistance in circuit on first rheostatic braking notch is R 2, R 6, on the second notch R 4, R 6, and on third notch all resistance is cut out by contact X, which will be in the position shown by dotted lines.

Some series winding in series with each armature is inserted on the parallel notches to enable the shunt motors to work in parallel.

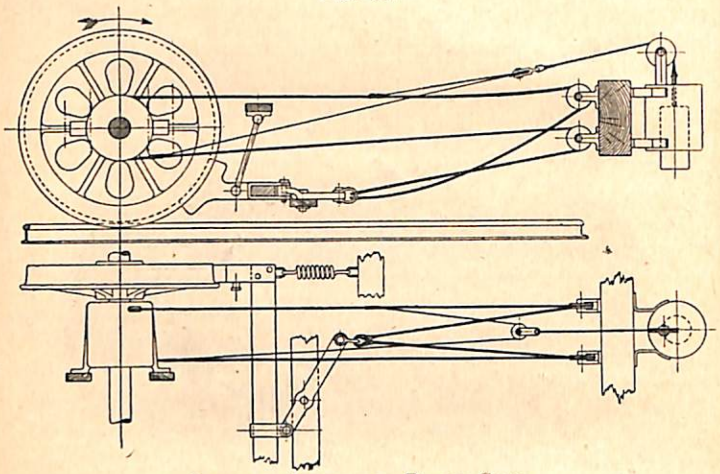
When changing from series to parallel or from parallel to series there is no resistance in main circuit, otherwise there would be heavy flashing at the controller contacts.

When changing from series to parallel some main resistance is inserted in series with the armatures to prevent abnormal rushes of current through the motor armatures before the field magnets become fully excited.

The series field winding has a considerable number of turns, but does not carry the full armature current, as it is provided with a shunt, through which passes most of the armature current.

To prevent the risk of the braking effect being lost

Fig. 61.



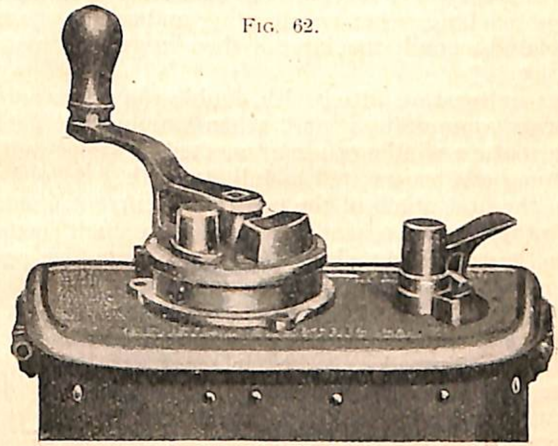
Johnson Automatic Brake Gear.

owing to the car being from any cause cut off from the source of supply, and to avoid the sudden generation of high voltages on the line, which might damage the car lamps and other apparatus, the arrangement shown in Fig. 58 is used.

If the car is descending a hill and the trolley pole leaves the wire the resulting increase in the voltage across the motor terminals causes an increase in the current through coil A and trips the switch X thus establishing a circuit from E to F and through resistance G to "earth," and the car can be brought down to a low speed by ordinary movement of controller.

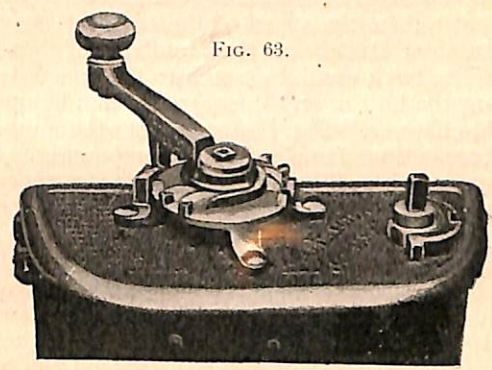
Controller R 7 has thirteen power and regenerating notches, seven of which are running notches. It has also three rheostatic brake notches, and is designed to control two 30-H.P. motors.

Fig. 62.



Automotoneer.

Fig. 63.



Durkin Controller Handle.

The connections are similar to those of the R 6 controller, with some small modifications.

Controller R 2 has twelve power and regenerating notches, eight of which are running notches.

It is provided with one emergency brake position. This controller is designed to work two 30-H.P. motors on level lines.

The Johnson Lundell Co.'s system of regenerative control is arranged so that the car motors act as series-wound machines when accelerating and running, and as compound-wound machines when regenerating and braking.

The motors are fitted with double-wound armatures and two commutators, and, when starting the car, all the armature windings are connected in series and the field magnets are excited to full strength.

On the first notch of the controller, current is admitted to the armature windings through a small rheostat.

On the remaining nine notches the armature resistance is cut out of action and waste prevented.

The Johnson Lundell controller is shown in Fig. 59, and is similar in appearance to an ordinary series parallel car controller.

The car is started by turning the large handle round as usual, but with the great advantage that every notch except the first is a " running " notch, and the speed of the car can be nicely varied to suit traffic conditions.

When it is desired to use the regenerative action of the motors and reduce the speed of the car, it is necessary to press a small button on the handle, and then move the controller back notch by notch to the speed desired.

Pressing the button on the controller handle operates the " field-changer," Fig. 60, and alters the motor field magnet connections from series to compound.

In common with all " electric " brakes, regeneration cannot suffice to hold the car on a grade, and it becomes necessary either to apply the hand brake or employ some automatic brake gear such as is shown in Fig. 61.

This automatic brake gear is controlled electrically by a solenoid connected to the car controller, so that when the controller handle is moved to the first notch the heavy iron core of the solenoid is lifted and the brakes are released from the car wheels. When the controller is moved to the " stop " position the solenoid allows the core to drop, and causes a stout steel cable to tighten up round a drum on the car axle, and thus apply the brake blocks to the wheels.

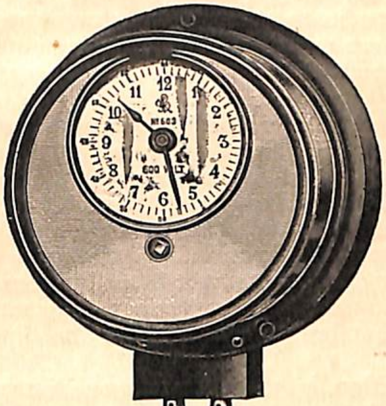
Automatic Acceleration.—A considerable economy in

current consumption can be effected by feeding up the controller at such a rate as to make the motors work at their most efficient load, and also reduce the loss in the rheostats. Several devices have been tried in practice which regulate the movements of the power handle so as to secure to some extent the best results. It is wasteful to turn on the power too quickly, and it is also objectionable to feed up slower than the occasion demands.

The Automotoneer (Fig. 62) is a device which controls the movement of the power handle through the action of an air dash-pot mechanism.

The movement of the controller handle from one notch

FIG. 63A.



TIME METER

to another moves a piston which drives the air out of a small dash-pot. The raised position of the piston locks the handle against further advance until sufficient time has elapsed.

The rate of advance can be regulated by adjusting the size of the air inlet of the dash-pot, and in any case the controller handle cannot be moved more than one notch at a time.

The device does not interfere in any way with the switching off movement.

Durkin Controller Handle.—This power handle is designed to regulate the rate of feeding up the controller, and consists of a special attachment for fixing to the top of existing controllers.

A hinged latch or "dog" is pivoted under the handle in such a way as to engage in suitably spaced notches and delay the movement of the controller handle for a moment on each position, thus insuring a steady rate of acceleration.

The latch does not engage in the notches when the handle is being moved back to the "off" position; and the device can be made to allow of the rate of feeding being such as will insure the most economical results.

Controller Time Meters.—To prevent waste of current some cars are fitted with recording Watt meters which record the amount of energy used during the day. These instruments are not in general use, as their indications are not sufficiently reliable and they require considerable attention to keep them in correct adjustment.

As it is possible to check motormen who use more current than is necessary by noting the time the controller is kept on the power notches and comparing this time with the miles run by the car, there are several meters in use to do this automatically.

A time meter is shown in Fig. 63A and consists of a strong lever clock movement fitted in brass case.

It is arranged to run only when the controller is on the power notches and thus record the time energy is being used.

A connection is made from one of the controller connections to operate a small magnet which stops the clock movement when controller is off and starts it when power handle is moved to first notch.

CHAPTER V.

BRAKES.

Car Brakes.—The brake gear and rigging form an important item in the car equipment, and many different types are in use, arranged to be operated by hand or power.

Hand Brakes.—The usual arrangement for hand working is where brake blocks are applied to the car wheels through the medium of rods and levers, actuated from a handle on the car platform.

The system of levers employed is such that the blocks are pressed very strongly against all the car wheels when the platform handle is pulled round by the motorman, and the friction thus produced tends to stop the car with a force depending on the pressure applied to the wheels and on the condition of the track rails.

The brake spindle on the platform is generally fitted with a "ratchet head," so that the handle can be set to the most convenient position for working.

When the brake spindle is turned a chain is wound round the lower end (Fig. 64), and draws forward the "draw rod" attached to the brake gear under the car.

To hold the spindle in position, so that the ratchet handle may be set or the brake held permanently on after the car has stopped, a foot "dog" or catch is provided, as shown.

Geared Hand Brakes.—Some forms of brake spindles are arranged with gearing at the bottom to obtain more purchase on the chain and thus reduce the amount of work thrown on the motorman.

Another arrangement sometimes employed is to operate the brakes by long hand levers on the platform, similar to those in use in railway signal cabins.

Brake Rigging.—The car truck carries the brake gear, and different types of gear are employed, according to the make of truck in use.

As representing the usual practice the diagram (Fig. 65) may be useful, and shows the fittings for a single four-wheel truck.

The chain from the brake spindle is attached to the end of the lever arm, which it pulls forward, thus causing the two brake beams to separate from each other.

The inside beam moves towards the car axle, and the other moves away from it.

The beam pushed towards the axle carries at each end a heavy cast-iron shoe, which is pressed hard against the rims of the car wheels.

The other brake beam is connected by two rods to the beam at the other end of the truck, so that blocks are also applied to the rear wheels.

When the brake chain is slackened by the motorman the shoes are pulled clear of the car wheels by strong spiral springs.

The long rods which connect the front and rear brake beams are screwed at the ends and fitted with nuts so that the shoes may be adjusted to brake equally on all the wheels.

Rear Brake.—It will be noticed that the brakes can only be operated properly from one platform at one time, and it is necessary to slack off the chain at one end if the brake is to be worked from the other platform.

Slipper Brakes.—Another form of hand operated brake is one where a long "slipper" faced with wood is applied to the surface of each track rail.

This style of **track** brake is suitable for use in descending steep grades, and is operated by a wheel or lever conveniently arranged alongside the handle for applying the ordinary wheel brakes.

An example of this class of brake is given in Fig. 66, where it will be seen that the track shoes can be pressed strongly down on the rails by a system of levers and toggles arranged to work from the platform by the usual chain.

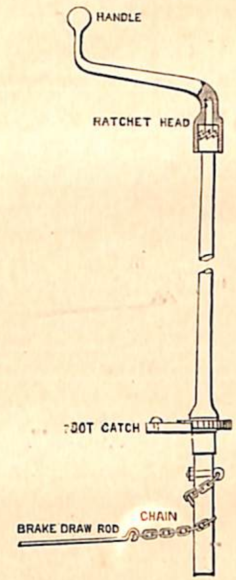
The hard wood blocks which are attached to the slippers can be removed at any time when they become worn.

Momentum Brakes.—To reduce the work thrown on the motorman when stopping the car, several arrangements have been devised by engineers to take advantage of the momentum of the vehicle and apply the brakes by this means.

In the Price momentum brake there is a sleeve which runs loose on the car axle and can be coupled thereto by a friction clutch operated by the motorman.

To the sleeve is attached a chain from the ordinary brake rigging on the truck.

Fig. 64.



Brake Staff and Fittings.

When the car is running and the sleeve is made to engage with the axle, the chain is wound up, and tightens the brake shoes against the car wheels.

The motorman has merely to operate the friction clutch, and is thus relieved of the labour usually spent in applying the brakes.

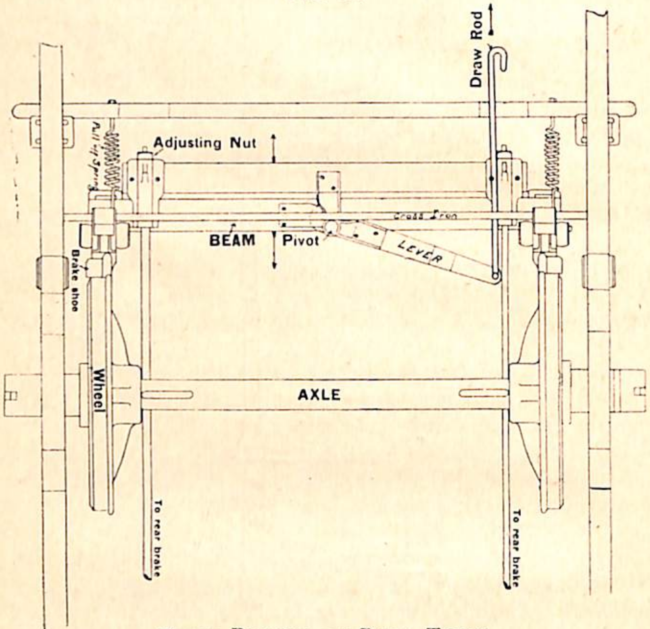
Air Brakes.—Another method of operating car brakes is to employ compressed air to do the work.

The air is admitted into a cylinder under the car, and acts on a piston connected to the ordinary hand brake rigging.

The air is compressed by means of a small air pump, and is stored in a reservoir at a pressure of about 70 lbs. per square inch.

The air pump may be driven by gearing from the car axle, or it may be worked by a small electro-motor with current taken from the trolley wire.

Fig. 65.



Brake Rigging on Brill Truck.

An automatic regulator is fitted so that the pressure in the reservoir is kept constant. When the pressure becomes reduced the regulator starts the pump, and when full pressure is restored the pump is either stopped altogether or discharges into the atmosphere.

A pressure gauge is fitted on the platform so that the motorman may see what pressure of air is available for braking.

From the air reservoir a pipe is taken to the platform

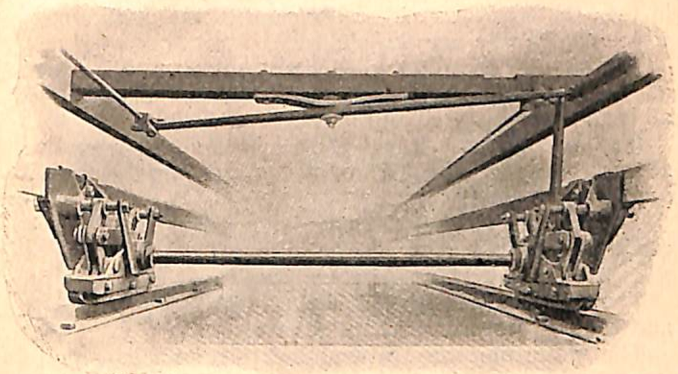
where the "operating" valve is fixed, and from the valve another pipe is led to the brake cylinder.

When it is necessary to apply the brakes, the operating valve is turned into a certain position, and allows the air from the reservoir to enter the brake cylinder and push out the piston and piston rod.

To slack off the brakes the operating valve must be turned so as to allow the air to escape from the cylinder into the atmosphere, and thus allow the piston to be drawn back into its original position by a strong spring and the brake shoes to fall back from the car wheels.

Christensen Air Brakes.—The Christensen air brake

Fig. 66.



Mechanical Track Brake.

equipments are arranged with either axle-driven or motor-driven compressors.

Motor-Driven Equipment.—A complete motor-driven set is shown in Fig. 67, and consists of the following essential parts :

(*a*) The **motor and compressor** which furnishes the compressed air.

(*b*) The **switch and fuse** for the motor.

(*c*) The **automatic regulator** which starts and stops the motor according to the variation of air pressure in the reservoir.

(*d*) The **main reservoir** for containing the compressed air.

(*e*) The motorman's **operating valve** by which air is admitted to the brake cylinder from the reservoir, or discharged from the cylinder to the atmosphere.

(*f*) The **air gauge** for showing the pressure in the reservoir. (Another gauge is sometimes fitted to show the pressure existing in the brake cylinder, or a single gauge having two pointers may be fitted.)

(*g*) The **brake cylinder** provided with a piston having its rod attached to the brake lever system on the car truck.

(*h*) The **train pipe**, which extends from one end of the car to the other, and is connected to the driver's valve at each end.

Motorman's Valve.—The motorman's valve is shown in Fig. 68, together with a diagram of the positions in which the handle may be placed.

The handle can be removed from the valve or replaced at the **lap position** only. In this position the valve has all its openings closed and is rendered neutral.

How to operate.—When the car is running the valve should be placed in the **slow release and running** position.

To apply the brake for an ordinary stop, the valve is moved to the **service stop** position, and this allows air to pass to the brake cylinder through a small opening.

The piston applying the brake is pushed out slowly and the car stopped without jerking.

The motorman may, after admitting sufficient air to the cylinder to apply the brakes, bring the valve back to the **lap** position, when the brake will still remain on.

To release the brake the valve is moved to **slow release and running** position, which allows the air to escape slowly from the cylinder. By moving to **quick release** position the air is allowed to escape very quickly from the cylinder.

When the valve is brought to **emergency stop** position, the air from the reservoir is allowed to flow through a large passage to the cylinder, thus putting the brakes on instantly and with maximum force.

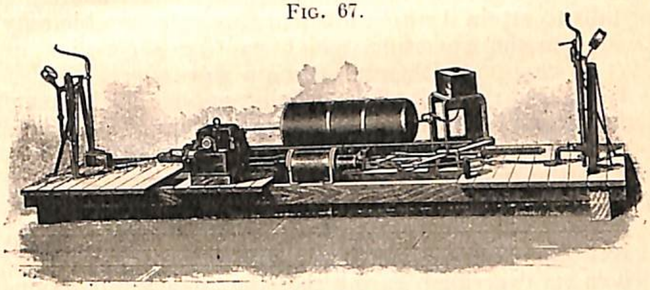
Generally, the brake leverage and the size of the brake cylinder are so proportioned that under ordinary circumstances with a dry rail the car wheels will not skid. If the rails are greasy the wheels will skid if the brake is

applied with maximum pressure, so under these conditions the motorman must be careful not to allow too much air to enter the brake cylinder, and if the wheels commence to skid at any time he must move back the valve handle to "**slow release**" to allow a little air to escape and let the brake slacken off slightly.

As the car comes to a stop the valve should be moved to **slow release** to prevent the disagreeable lurch the car may make. When coasting down hill the valve should be moved over to **service-stop** position for a little and then back to **lap position.**

If too little air has been admitted to the cylinder the application may be repeated, or if the brake has been applied too strongly the handle may be moved for a second or two to the slow release position and then back

Fig. 67.



Christensen Air Brake Equipment.

to lap. The driver should endeavour to manipulate the valve so that the car is brought to a standstill with one charge of air in the cylinder.

He should not make a hard application when approaching a stopping place, and then have to release the brakes and make a fresh trial.

Care must be taken not to apply too much pressure, as the wheels may skid, and even though the air is released smartly, flats may be formed on the rims and cause trouble.

When changing ends at a terminus the brake may be left on and the valve handle taken to the other platform, where the brake may be released when found necessary.

Never run with the valve-handle in the **lap** position, except when the brakes are applied.

To start the air compressor it is only necessary to close the small switch provided, which will allow current from the trolley to reach the automatic governor.

Automatic Governor.—If the pressure of air in the reservoir is low the governor closes the circuit and allows the current to reach the motor which drives the air pump.

The motor continues to run until the reservoir pressure rises to the proper amount, when the governor cuts off the current and stops the motor until again required. The pressure in the reservoir is kept at about 70 lbs. minimum to 80 or 90 lbs. maximum per square inch.

Faults.—If the motor-driven compressor fails to start, the trouble may be due to the fuse having blown, or possibly to a defect in the automatic governor.

If the pressure in the reservoir passes the maximum or fails to attain it after sufficient time, the trouble may be due to the governor, which may need cleaning or may be clogged with some foreign substance.

If the brakes slack off after being applied in the usual way, and while the valve is at lap position, the air may be escaping from the brake cylinder through a leak in one of the pipes, or the piston may not be fitting the cylinder properly.

Axle-driven Compressor.—The Christensen axle-driven equipment is similar in principle to the motor-driven set described, except that the air-pump is mounted on the car axle and driven continuously so long as the car is running.

The air from the compressor is taken to a large reservoir as usual, and passes through the governor before entering it.

The governor is so constructed that when the pressure in the reservoir reaches a certain maximum (about ninety pounds per square inch) it opens a small valve and allows the air from the compressor to discharge freely into the atmosphere.

When the reservoir pressure falls, either through the application of the brake or from other causes, the governor closes the opening to the atmosphere, and the compressor pumps air into the reservoir until the maximum pressure is again attained.

The operating valve and general equipment of the axle-driven brake set are similar to the motor-driven

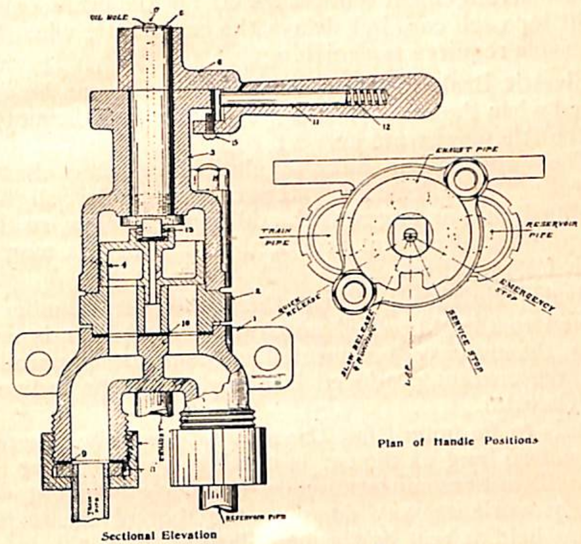
equipment, and the instructions given regarding the application of the brake are exactly the same in both instances.

Air Track Brakes.—Another form of compressed air brake is shown in Fig. 69, and acts on the track instead of against the wheels.

Referring to the sectional view of the brake cylinder its action will be easily understood.

The compressed air is admitted through an orifice into the cylinder (A) and presses down the piston (B), thus

Fig. 68.



Motorman's Valve and Positions.

forcing the wood-faced slipper (H) into frictional contact with the rail (K).

Four of these brake cylinders are fitted to a car, and are all connected by air-pipes to the controlling valve fixed on the car platform.

A supply of compressed air is kept under the car in a strong reservoir at a pressure of about sixty pounds per square inch.

The air compressor may be driven by a small motor, or by the axle of the car through gearing.

A pressure-gauge is fitted to show the pressure of air in the reservoir.

This form of air-brake is useful for descending steep grades or for making rapid stops to prevent accidents, and is operated in the same way as the air-brakes previously described.

Reservoir Systems.—Instead of having an air compressor on every car on the system, a larger reservoir is sometimes fitted and is filled with compressed air at the depôt or at some convenient point along the route, where a large compressor is installed.

This arrangement reduces the cost of the brake equipment for each car, but delays the car a little when the reservoir requires replenishing.

Electric Brakes.—A strong brake action can be produced when the car is running, by connecting the motors so that they generate current.

The application and regulation of this electric "brake" is effected by the car controller slightly modified, and arranged with additional notches, so that the amount of current produced by the motors may be varied as required.

Brake Notches.—When the controller handle is moved to the "brake" notches while the car is running, the motors are connected as generators in parallel, and the current produced is absorbed in the ordinary car rheostat.

It is to be noted that the motors can only generate current so long as the car is moving, and therefore the car will not remain stationary if on a grade, but will slowly work its way down to the foot of the incline unless held at rest by the hand-brake.

In Chapter IV. on controllers, the connections on the "brake" notches of different types of controllers are described and explained.

"Emergency Stop" Positions.—On some controllers no brake notches are provided, but the reversing lever can be pulled into an "emergency stop" position where the motors are simply short-circuited, and pull the car up with a jerk.

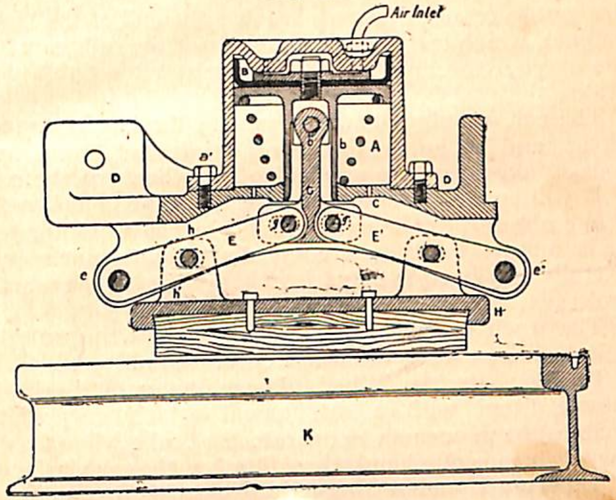
With controllers arranged with several brake points it is possible to apply the braking effect gradually or with full force as required.

The whole of the braking effect is done by the motors through the gear-wheels of the running car.

Applying Electric Brakes.—To apply the electric brake it is necessary to move the controller handle round to the brake notch which agrees with the speed at the moment, and then to move it again notch after notch as the car slows down until the last point is reached and the car comes to a standstill.

Rapid Stops.—This form of car brake is powerful in action, and very rapid stops can be made if care is taken

Fig. 69.



Section of Hewitt and Rhodes' Air Track Brake.

to apply it quickly to the notch which gives maximum effect without actually skidding the wheels.

It is therefore necessary to consider the speed at the moment and the condition of the rails to obtain best effects.

Service Stops.—For making ordinary service stops the brake should be applied as smoothly as possible, to avoid damaging the motors or jerking the car and passengers.

Electro-magnetic Brakes.—As the "rheostatic" electric brake described above is somewhat severe on the motors, several arrangements have been devised by engineers in order that a portion of the current spent in simply heating the rheostat may be usefully employed in retarding the car's progress.

The usual idea is to pass the current from the motors through the coils of large electro-magnets, which operate brake gearing on the car axles and wheels or on the track rails.

Westinghouse Magnetic Brakes.—This type of magnetic brake as fitted to a 4-wheel truck is shown in Fig. 70, and to a maximum traction truck in Fig. 70A.

In this case the motor current, after passing through the controller and rheostat, reaches the coil of the large magnet, which hangs immediately over the rail, causing the magnet to cling to the track and act as a slipper brake.

The car, running forward, pushes the track magnet along, and by an arrangement of pivoted levers and rods, brake-shoes are applied to the wheels of the car.

It will be understood that with this type of magnetic brake not only is the car retarded by the work thrown on its motors, but the current produced is to some extent usefully employed in actuating the brakes on the wheels and rails.

The track magnet is supported clear of the rails by spiral springs when the brake current is off.

In Fig. 70B the Westinghouse magnetic brake is shown fitted with a mechanical attachment which enables the motorman to operate the brake when necessary by means of a hand wheel fitted on the car platform.

Thomson-Houston Magnetic Brakes.—Another form of magnetic brake is given in Fig. 71, and consists of a large magnet, which is attracted strongly to the rail when excited by current from the car motors.

When the controller is moved back to "off" position, or when the car stops, the magnet is pulled up clear of the track by suitable springs.

Two magnets are fitted on single trucks, and four on double-truck cars.

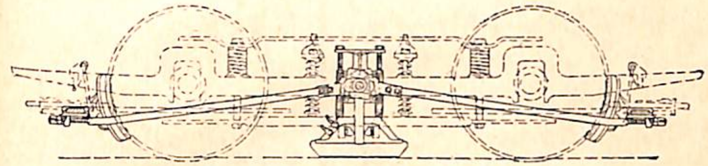
The downward drag produced by the magnets tends to increase slightly the weight on the car wheels and prevent skidding.

This brake is also arranged to be applied mechanically by means of hand wheels fitted on the car platform.

Magnetic Disc Brakes.—Instead of employing electro-magnets arranged to be attracted to the rails, they may be constructed in the form of discs and mounted on the car axle.

With this style of magnetic brake the usual arrangement is to have a flat disc keyed to the axle and running close to another disc which is held stationary on suitable

Fig. 70.

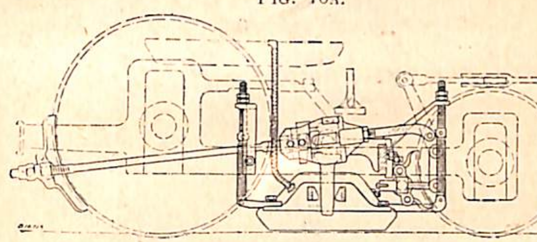


Westinghouse Magnetic Brake.

supports. The stationary disc has coils of insulated wire imbedded in it, and when current from the motors is allowed to pass through the coils the axle-disc is strongly attracted, and the friction produced between the two discs tends to stop the wheels from revolving, and bring the car to rest.

Operating Magnetic Brakes.—With all the magnetic brakes mentioned the operation is practically the same

Fig. 70A.



Westinghouse Magnetic Brake (Another Type).

as for the rheostatic electric brake, and the same care is necessary to prevent jolting the car or damaging the motors.

"Regenerative" Braking.—From what has been mentioned previously regarding electric brakes the reader will understand that the current produced by the car motors may be regulated in amount by varying the amount of rheostat, and may be employed to operate track or wheel brakes.

The motor current may also be used to heat the car interior by passing it through suitable resistance coils.

Instead of using the current in any of these ways it

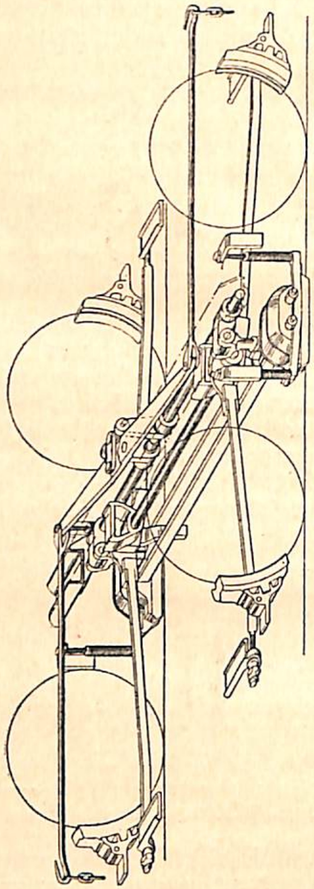


Fig. 70b.

Westinghouse Magnetic Brake with Mechanical Attachment.

may be returned to the trolley wire, and thus serve to drive other cars on the line.

The special apparatus used in connection with regenerative control is described in another section of this book.

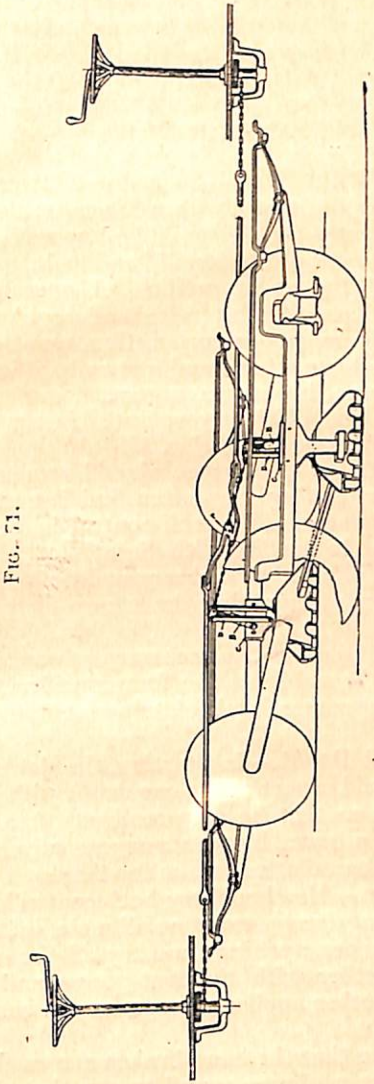


Fig. 71.

Thomson-Houston Magnetic Brake with Mechanical Attachment.