THE ELECTRIC TRAMCAR HANDBOOK

THE ELECTRIC TRAMCAR HANDBOOK

FOR MOTORMEN, INSPECTORS, AND DEPÔT WORKERS

BY

W. A. AGNEW

SEVENTH EDITION

LONDON
H. ALABASTER, GATEHOUSE & CO.
4, LUDGATE HILL, E.C.

1915

[Price 1s. 6d. net.]

CONTENTS.

INTRODUCTION TO FIRST EDITION.

THIS handbook has been compiled with a view of bringing together, in convenient form, a simple description of modern electric tramcars, and to give instruction regarding the proper operation of these vehicles on the road.

The recent great development of electric tramway systems in this country has occasioned a widespread demand for capable and intelligent men to act as motormen, and in the car sheds and depôts of the various companies and corporations a large and increasing number of engineers and assistants find daily employment.

Information is given in the following pages which will be useful to men wishing to qualify for positions as motormen and to those who are learning to operate cars for the first time.

It will also be of assistance to those readers who are earning a livelihood at such work, and who desire to know more about the vehicles under their charge, with the view of becoming more expert at their work or securing promotion to better positions on the staff.

To men engaged in car depôts and repair sheds the chapters dealing with car equipments and apparatus will be of interest, as also the chapter relating to "faults and breakdowns," and may assist them to more fully understand the machinery under their care and indicate the precautions necessary to ensure its proper working.

In taking up the subject of electric cars the novice would be well advised carefully to read and master each chapter in the order given, otherwise he may find some difficulty in understanding the matter dealt with towards the end of the book and be needlessly discouraged from further effort.

Many people think electrical machinery so mysterious and complicated in action as to be quite beyond their understanding. While it must be admitted that some electrical appliances are rather complicated in construction, yet a great deal of the mystery vanishes when the simple fundamental laws which govern the electric current have been mastered and the knowledge thus gained made use of.

The first chapter of this handbook explains some of these laws relating to the current, and mentions the different effects to which the passage of a current may give rise when sent along a suitable "conductor."

Mention is also made of the methods of producing and controlling the electric current, and the meanings of the units "volt," "ampère," and "ohm" are explained in simple language.

Some motormen know nothing whatever beyond the actual manipulation of the platform handles, and yet are able to run their cars with safety and dispatch under ordinary circumstances; but when a breakdown occurs they are unable to effect a remedy, and, if a defect develops in certain parts of the equipment, may allow their cars to get beyond control, with disastrous consequences to all concerned.

A motorman of this class, who does everything in a mechanical fashion, cannot appreciate the possibilities of economically operating his car, and cannot understand the meaning and reason of the rules issued to him by his superiors.

It is evident that the more a man knows about his work the better is his chance of securing steady employment and better pay.

The best motorman is the one who understands the

apparatus he is handling, and operates it as instructed by his employers, and in accordance with the dictates of common sense.

He must be physically strong enough to control the car under all conditions and to withstand the constant exposure to the weather on a car platform.

He is expected to keep himself mentally alert and capable of performing his duties without accident, and to this end must rigidly abstain from stimulants during working hours, and pay attention to the ordinary rules of health and good living.

A motorman, to be able to operate safely a heavy car through the crowded streets of one of our large cities, and on the severe grades and slippery tracks which often exist, must necessarily keep himself in fit condition, otherwise he risks being put aside for abler men, and may have to take up less exacting duties at a correspondingly less rate of pay.

Tramway managers are always ready to recognise good men and retain their services, while being just as anxious to get rid of ignorant and unsatisfactory men who are always in trouble.

The writer will be pleased to receive criticisms and suggestions for improvement in future editions, should such be called for, and he wishes to thank the British Thomson-Houston Company, the British Westinghouse Company, the Brush Electrical Engineering Company, the British Electric Car Company, Messrs. Dick, Kerr and Co., Messrs. Estler Bros., Messrs. Bruce Peebles and Co., and other firms for their kindness in furnishing diagrams and descriptions of the various machines and fittings manufactured by them.

W. A. AGNEW.

CHAPTER I.

THE ELECTRIC CIRCUIT.

Conductors and Insulators.—To convey electricity to any distant point, a suitable conducting path must be provided along which it may travel.

If a continuous flow of current is required the conducting path must be arranged in a complete loop or circuit, so that the current may arrive back again at the generating point.

In electric tramway systems the overhead trolley wire conducts the current to the cars, and the rails serve to complete the circuit back to the generating station.

Many different materials are able to "conduct" electricity, but certain of these are better than others, as they offer comparatively little resistance to the passage of the current. Silver is the best conductor, but copper is most commonly used. Some metals and alloys offer great resistance to the current, and are used only where this property is found serviceable.

Materials which are unable to conduct electricity are termed "non-conductors" or "insulators."

The insulators in general use are wood, indiarubber, asbestos, mica, cotton, paper, etc., and these are used when it is necessary to protect a conductor from leakage or to keep it from coming in contact with other conductors.

When a bare conductor is used it must be supported at intervals on suitable insulators. A familiar example of this is seen in telegraph or telephone lines.

When conductors are bunched together or are likely to touch other conductors, they are usually protected by a covering of insulating material.

Properties of the Current.—When electricity is flowing along a metallic conducting path it shows its presence in two ways:

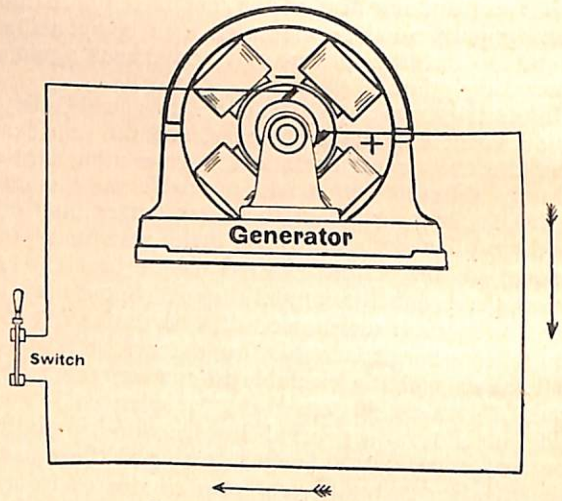
(A) By heating its conductor.
(B) By a magnetic effect.

Heating Effect.—The first-noted property is taken advantage of to produce light, as in electric glow lamps, and electric stoves are made in which the current is employed to produce the desired warmth.

The amount of heat produced in a conductor depends on its resistance and on the rate at which the current flows along it.

Magnetic Effect.—The magnetic effect produced by a current is easily shown by a simple experiment. Take a short bar of soft iron and coil round it some insulated

FIG. 1.



SIMPLE ELECTRIC CIRCUIT.

wire. On passing a current through the wire the iron bar will be rendered strongly magnetic and will attract iron or steel at both ends.

Such an arrangement is termed an **electro-magnet,** and the iron remains in the magnetic state so long as the current is kept circulating through the exciting coil; the magnetism vanishes almost completely when the current is stopped.

The magnetic effect of a current is usefully employed in many different machines and devices, such as electric bells, telephones, electro-motors, etc.

Simple Circuit.—The diagram, Fig. 1, shows a simple electric **circuit** in which the current circulates from the **positive** terminal + of the "generator" through the conducting path, in the direction of the arrows, to the **negative** terminal —.

Electric Pressure.—If we measure the pressure which maintains the current in this simple circuit we find it is highest at the positive terminal, and gradually falls to zero at the negative end of the conducting path.

The "pressure" existing between two points of an electric conductor is measured in **volts,** and is sometimes called "voltage."

Resistance.—The reduction of pressure in the circuit is due to the **resistance** which the conductor offers to the flow of current, and the amount of resistance depends on the size of the conductor, on the length of the circuit, and on the material of which the conductor is composed. The "resistance" in a circuit is measured in **ohms.**

Current.—The rate at which a current flows through a circuit depends on the voltage existing between the ends, and on the amount of resistance offered by the conductor.

The "rate" of flow (sometimes called the strength of the current) is measured in **ampères.**

Generation of the Electric Current.—There are several methods by which electricity can be produced, but the only commercially successful way, so far, is to generate it by means of **dynamo-electric machines.**

Dynamo-electric machines, or "dynamos," depend for their operation on a simple fundamental principle first made known by Michael Faraday in 1831. This scientist discovered that when a complete conducting loop or coil was revolved before the poles of a magnet a current of electricity was generated in the coil and continued to flow as long as the motion of the coil was maintained.

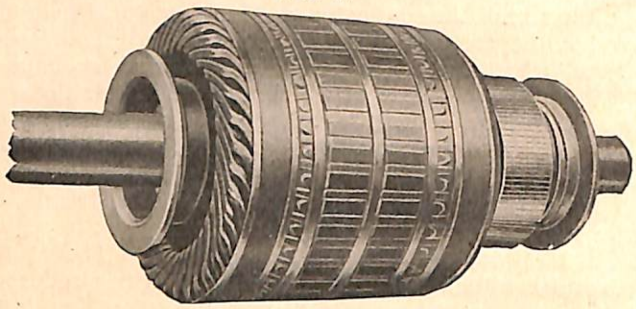
Modern Generators.—In modern dynamos for producing continuous electric currents very powerful electro-magnets are employed, and an **armature** carrying many coils of copper strip or wire is rapidly revolved between the poles of the magnets. The current generated in the revolving armature coils is brought to a **commutator** mounted on the same shaft, and is collected therefrom by metal or carbon **brushes** which press against the surface of the commutator. The current generated in the armature is alternating in direction, and the action of the commutator is to convert it into a current flowing in one direction only, hence the terms **continuous** or **direct** current.

The commutator usually consists of copper bars or **segments** built into drum form, each segment being connected to the end of an armature coil and insulated from neighbouring segments, and also from the shaft, by strips of mica.

The whole commutator is bound firmly together, and is turned and polished to allow the collecting brushes to rub smoothly and closely on the revolving surface.

Complete Armature.—In Fig. 2 is shown a com-

Fig. 2.



Armature.

plete armature with commutator mounted on shaft and arranged to be driven by a belt from a steam engine or other source of power.

When such an armature is mounted and revolved between suitably-shaped magnets it is able to furnish a continuous current of electricity.

A complete dynamo is shown in Fig. 3.

Generator or Motor.—An important point to note here is that a dynamo-electric machine can be used as a **generator** or as a **motor**, as desired. If driven from a steam engine the machine will supply current, and if supplied with current from some other source it will run as a motor and be available for driving machinery.

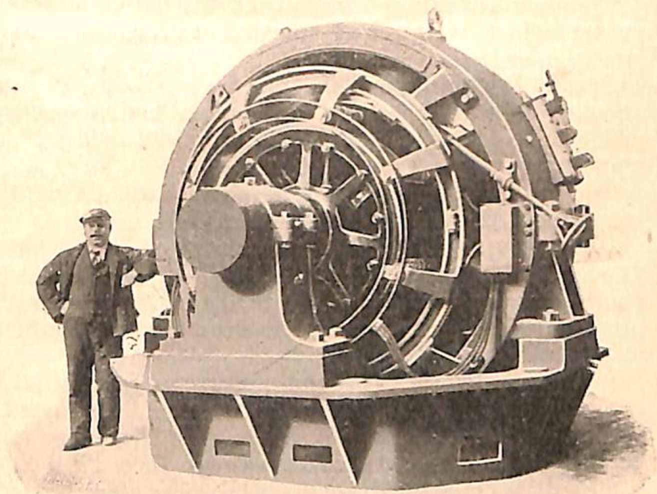
This useful reversible property of the dynamo-electric machine is taken advantage of on electric cars in order

to obtain an "electric brake" action, as will be seen later when the subject of brakes is discussed.

Field Magnet Connections.—The electro-magnets of a dynamo-electric machine—**field magnets**, as they are usually called—are excited by coils of insulated copper wire through which current is passed.

In some types of machines these coils consist of a few turns of heavy wire, and the whole of the armature current passes through them. This method of exciting the magnets is termed **series-winding**, and is gener-

Fig. 3.



Traction Generator.

ally employed in tramcar motors on account of the necessity of obtaining a strong effort from the motors to start the car and climb steep gradients.

In other machines the field-magnet coils consist of a large number of turns of comparatively small wire, and only a small portion of the armature current passes through the coils. This arrangement is called **shunt-winding**, and is used on motors which have to run at constant speed or for generators having steady loads.

Shunt wound motors are used on some cars arranged for regenerative control.

A combination of shunt and series winding is used on some machines, and the field-magnets have two windings, one of thin wire, which takes a shunt current, and the other of thick wire, which carries the main armature current. This arrangement is termed **compound-winding,** and is used for generators where the current taken from the machine varies widely, as in tramway work, etc., the effect of the series coils being to keep the voltage of the machine constant, or slightly increase it as the load becomes heavy.

Compound-winding is employed for motors where a strong effort is required for starting, as well as a steady speed when running.

Speed Regulation.—The pressure of the current supplied from a generator will depend on the speed at which it is driven and on the strength of its field-magnets.

Conversely, the speed of a motor depends on the pressure of the current with which it is supplied, and on the strength of its field-magnets.

Accordingly, where the speed of a motor has to be varied, arrangements must be made to vary either the pressure of the current or the strength of the field-magnets.

In the case of series-wound motors, as fitted to electric cars, the former arrangement is usually adopted.

Rheostats.—This varying of the supply voltage may be done by causing the current to go through a long length of wire or strip made of some material which offers great resistance to the passage of the current, thus reducing the pressure; such a device is called a resistance coil or **rheostat,** and is generally constructed of fireproof materials and divided into sections with terminals attached, so that the amount of resistance in use may be altered as required.

Reversing Motors.—To reverse an electro-motor it is necessary to change the direction in which the current flows through the armature or through the magnet coils. Fig. 4 explains how this reversal can be accomplished in a series-wound motor.

In the first diagram *(a)* the current is flowing

through the magnet coils and armature in the direction of the arrow heads, and the armature revolves in a certain direction.

In the second diagram (*b*) the current flows through the magnet coils as before, but the direction through the armature is changed, and it now revolves in the opposite direction.

Electric Car Reversing Gear.—In electric cars this changing of the armature connections is effected by a reversing switch fitted in the controllers, and operated by a small handle conveniently placed.

Fig. 4

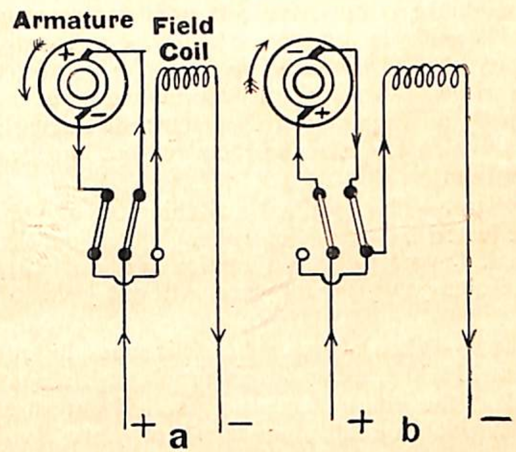


Diagram of Reversing Switch.

Motor "Back Pressure."—When an electro-motor is running it produces a "back pressure," depending on the speed of the armature and the strength of the magnets.

If a series-wound motor has little or no work to perform it will run up to a high speed, in order that its back pressure may almost equal the voltage of the supply current, and thus allow only a small amount of current to pass through the machine.

When the motor is heavily loaded and has to perform a large amount of work its speed drops, and the reduction in the back pressure which occurs will allow a greater current to flow through the motor in order to do the necessary work.

Starting Loaded Motors.—It will therefore be understood that if a motor is so heavily loaded as to prevent the armature from revolving, an enormous rush of current may pass through it, as no back pressure is being produced by the machine, and the supply current has only to overcome the comparatively slight resistance offered by the copper wire in the armature and field-magnet coils.

It is important that when heavily loaded motors have to be started, as on an electric car, the supply current should reach the motor terminals at a low pressure to begin with, and the pressure should be gradually increased as the car speeds up and the motor back pressure rises, in order to prevent damage to the machines by an excessive rush of current through the windings, which would make them red-hot and destroy the insulation.

Controllers.—This gradual switching-on of the current is effected by the "controller" fixed on the car platform and arranged in conjunction with a rheostat to effect the changes gradually and without jerks to the motors.

Switches.—When a gap or break is made in an electric circuit in which a current is circulating, a spark is produced at the point of rupture, and if only a small gap be provided a continuous spark or "arc" will be set up and will continue so long as the current circulates or until the contact points are burned away and the gap between increased. With powerful currents, such as are used in tramway work, this electric arc may prove very destructive, and accordingly means must be provided to break circuit very quickly, and to introduce a wide gap so that the spark is destroyed at once.

An apparatus for opening an electric circuit is termed a "switch," and is generally fitted with an insulated handle to protect the operator from shock; by means of strong springs the circuit is broken as rapidly as possible, and the arc destroyed immediately.

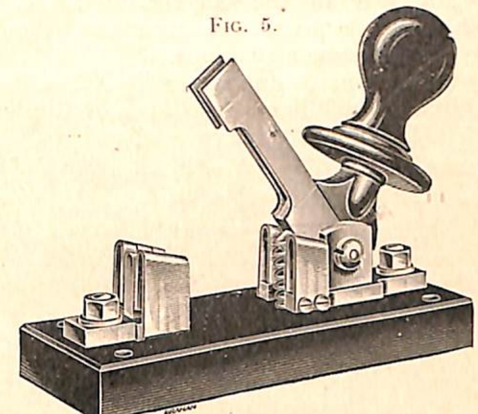
A typical form of switch mounted on an insulating base is shown in Fig. 5.

In car controllers, or in switches not fitted with spring action, the operator must supply the necessary rapidity of action himself, and never break a heavy current slowly, as it may cause serious damage to the contacts of the apparatus.

Defective Circuits.—If a gap or break occurs in an electric circuit, due perhaps to the conductor breaking or working loose at some point, the current will cease to flow, and an "open circuit" is said to exist.

When normal conditions prevail in an electric circuit the current flows along its proper conducting channel,

Fig. 5.



Quick Break Switch.

but should some easier path be provided offering less resistance the current will prefer to travel by it, and a "short circuit" is said to exist, or simply, a "short."

When the protective covering of a conductor becomes damaged, and the bare conductor comes in contact with the ground or earth, or with some other conducting material connected to the negative side of the circuit, there is said to be a "ground" or "earth" on the circuit.

Useful Rules.—To find the resistance of a circuit it is necessary to divide the voltage existing between the ends of the circuit by the rate of the current in ampères.

Example: To send fifty ampères through a certain circuit it is found that the pressure necessary at the terminals is 500 volts. What is the resistance of the circuit in ohms?

$500 \div 50 = 10$ ohms.—Ans.

To find the voltage existing in a circuit the current in ampères should be multiplied by the resistance of the circuit in ohms.

Example: A current of fifty ampères is flowing through a circuit of ten ohms resistance.

What voltage exists between the terminals of the circuit?

$50 \times 10 = 500$ volts.—Ans.

To find the rate of the current in ampères the pressure in volts between the terminals should be divided by the resistance in ohms.

Example: How many ampères will 500 volts send through a circuit which has a resistance of 10 ohms?

$500 \div 10 = 50$ ampères.—Ans.

CHAPTER II.

SYSTEMS OF ELECTRIC TRACTION.

Different Systems.—Several different systems of supplying electric cars with current have been proposed and tried in practice, and may be classified as follows:

(*a*) Accumulator systems.
(*b*) Third-rail systems.
(*c*) Surface-contact systems.
(*d*) Conduit systems.
(*e*) Overhead trolley systems.

Accumulator System.—With this system each car is equipped with an electric storage battery or **accumulator,** which may be charged with current at the car depôt, and the car motors derive their supply of power from these accumulators.

The speed of the car may be controlled by connecting the individual cells of the battery in groups, and thus obtaining different voltages, or a rheostat may be used for the same purpose.

Each car forms an independent unit, and may be run anywhere on the line until its storage battery becomes exhausted and requires re-charging.

Up till the present time, however, accumulator systems have not proved satisfactory on account of the great weight of the batteries and the expense of keeping them in proper condition.

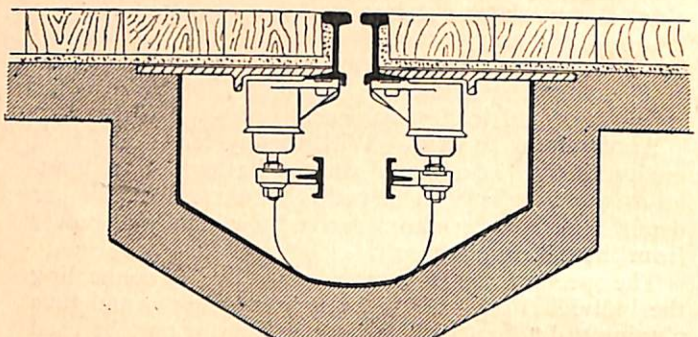
The vibration to which the cells are subjected on a street car, and the heavy duty they have to perform prove fatal to the longevity of the accumulator, thus rendering this attractive system of traction commercially impossible.

Third-rail System.—This system is suitable only where the line is fenced and private property, as the current is here brought to the car by a contact rail, which is mounted on insulators and fixed between or alongside the track rails, and as the contact rail is quite exposed and liable to be touched it is not suitable for use on public streets.

This system of traction is adopted on several suburban and underground railways in this country. The current is collected from the third rail by a metal collecting-shoe or "skate," and after passing through the car motors returns to the generating station by the track rails or by another contact rail laid alongside.

Surface Contact System.—In this system current is collected from small metal studs which automatically become "live" or charged with current when the car

FIG. 6.



CROSS-SECTION OF CONDUIT.

is immediately over them, and are switched out of service and become "dead" when the car has passed.

These contact studs are supplied by underground cables with current from a central power station.

To collect the power from the studs a long collecting "skate" is fitted under each car, and is arranged to rub against the tops of the studs, which project a little above the surface of the street. The current, after passing through the car motors and other apparatus, gets back to the power house by the track rails as usual.

This system is in use on a few lines in this country, and may be used more widely in the future as the design and construction of the apparatus are improved and it is rendered more certain in action.

Conduit System.—This system derives its name from the fact that the conductors supplying power to the cars are fixed below the road surface in a shallow trench or **conduit,** the current being collected from them by a contact "plough" which is carried on the truck under the car, and passes down through a narrow slot provided in the top of the conduit.

A cross-section of a conduit is given in Fig. 6, and a car-truck fitted with collecting plough and the necessary gear is shown in Fig. 7.

It will be seen that two conductors are fixed in the conduit (one being used as a return), and that they are constructed of T-iron, and supported clear of the sides by insulators fixed at suitable distances along the trench.

Traps are provided at frequent intervals along the line to allow of the "plough" being withdrawn from the conduit when necessary, and the conduit is well drained to prevent rain-water accumulating and "short-circuiting" the conductors.

This system is employed on (some of) the tramways of the London County Council, and may be used in conjunction with a trolley system—that is, the conduit may be used in the busy centre of a city where overhead wires are objected to, the overhead trolley system being used for outlying lines.

The cars in this case require to be equipped with both trolley pole and collecting plough, and at the junction of the two systems these are changed over as required.

Overhead Trolley System.—This system is most widely adopted in this country, and although by no means picturesque it possesses the merits of simplicity and cheapness of construction, together with ease of repair and manipulation.

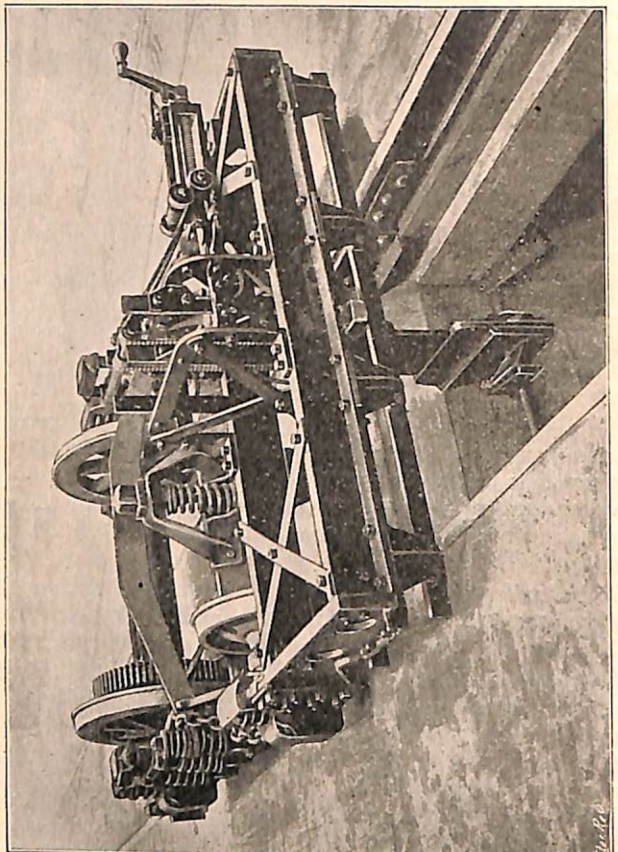
With the trolley system the cars are supplied with current from a bare copper wire suspended overhead, the power being collected therefrom by a long pole fixed to the roof of each car and carrying a small metal "trolley" wheel, arranged to press against the live conductor and run smoothly along its under surface.

Usually a single trolley wire is fixed over each track, and the current, after passing through the car, returns to the power station by the rails in the usual way

Path of Current.—In Fig. 8 is given a diagram of the path of the current in the trolley system of electric traction.

From the generating station the current is led by

Fig. 7.



Truck and Plough for Conduit System.

underground cables to section boxes or switch pillars situated at suitable points along the route, and after passing through switches the current reaches the overhead conductor, and can be collected by the running cars.

Circuit Breakers.—Each "feeder" cable leaving the power station is connected through an **automatic circuit-breaker,** a device which is arranged to cut off the current if it exceeds a certain safe maximum, and thus prevent damage being done to the cables and generating machinery.

Fig. 8.

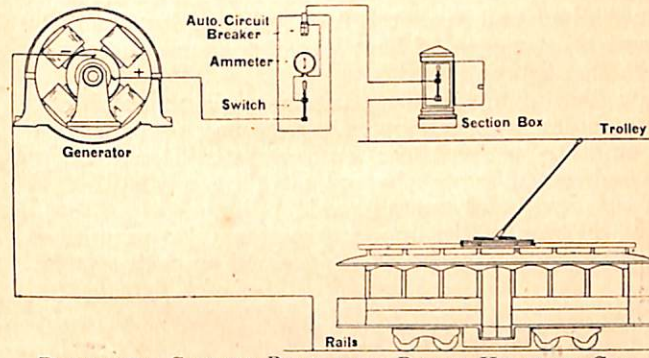
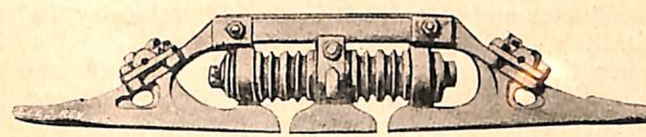


Diagram of Current Path, from Power House to Car.

This excessive rush of current might be caused by the trolley wire falling on the track rails or by some defect occurring in a car equipment, or perhaps a leak might develop on the feeder cable itself owing to its protective covering becoming damaged.

Fig. 9.



Estler Bros.' Section-Insulator.

The "feeders" are usually laid in metal or earthenware pipes under the street surface, and manholes are arranged at intervals to allow of inspection or renewal being effected.

The overhead trolley wire is supported above the track at short intervals by insulating "hangers" and "ears," which are, in turn, supported either by span wires attached to side poles, or rosettes fixed to buildings, or by centre and side-bracket poles fixed near the track.

Section Insulators.—The trolley wire is divided into sections not exceeding half a mile in length by **section-insulators,** a type of which is shown in Fig. 9.

It will be noticed that the ends of the trolley wire are attached to the insulator, and that these ends are kept quite distinct and insulated from one another, and the current thus prevented from passing from one section of the line to the other.

The idea of fitting these insulators is to be able to locate faults or breakdowns which may occur on the line and to prevent the entire system from being knocked out of service by some trifling mishap occurring at some point on the road.

The division of the line into sections also permits of a fairly even voltage being maintained on each section.

Fig. 10.

Overhead Frog for Centre-running Trolley.

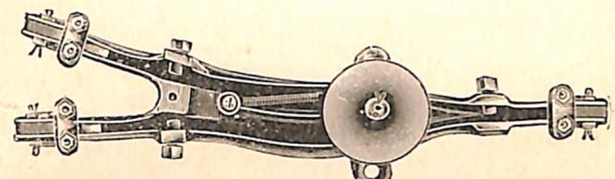
Overhead Junctions.—Where points and crossings occur on the track it is necessary to provide suitable devices to keep the trolley wheel always in contact with the conductor and to guide it in the path taken by the car itself.

When the car is provided with a fixed or "centre-running" trolley head it is sufficient to provide these overhead crossings and frogs with suitable grooves and ridges to guide the trolley wheel in the proper direction (Fig. 10). When a side-running or "swivel-head" trolley is used the overhead gear has to be provided with movable tongues and guides so that a continuous and unbroken path is provided for the trolley wheel when changing from one conductor to another; otherwise the head might twist round and leave the wire.

An overhead frog, adapted for use with swivel-head trolleys, is shown in Fig. 11. In the next chapter both centre and side-running trolley heads are illustrated and described.

Guard Wires.—Where there is a risk of telephone and telegraph wires falling across the "live" trolley wire and becoming charged with current, "guard-wires" are erected directly above the trolley wires, and are connected to the rails, so that if a wire falls and makes contact with both guard and trolley, a "ground" will be established, and in all probability the fallen wire will be fused through and will fall, harmless, to the street. If a number of wires were to fall at once, or if the guard-wire itself were to fall across the trolley wire, the resulting heavy rush of current to the rails would cause the automatic circuit-breaker in the power-station to open, and the current

Fig. 11.



Mechanical Frog for Swivelling Trolley.

would thus be cut off until such time as the fallen wires were removed and the "breaker" replaced.

It will be seen that the "guard" wires are simply employed to prevent falling wires from remaining "live" or charged, to the possible danger of pedestrians on the streets or passengers on the cars.

Precautions against Shocks.—It is important to note in this connection that the current supplied to electric cars is at a comparatively high pressure (500 volts), and considerable risk is run by anyone touching a conductor carrying such a voltage.

In the case of the trolley wire falling to the ground and remaining charged it must never be touched with the bare hand, but only with a dry stick or board, or, better still, by using rubber gloves to protect the hands.

Never catch hold of a live wire with a thin handkerchief or any damp material.

If a trolley wire falls in a busy thoroughfare it is advisable to make the wire dead at once by drawing it firmly across the track rails and keeping it in contact with them until the repair gang or engineer arrives.

If, however, the wire falls in a street where there is little risk of anyone touching it, it may be held clear of the rails, to allow of the power being maintained on the line.

If a live wire is in contact with any person and he is unable to extricate himself, endeavour to draw him clear by pulling his clothing, if dry, but be careful not to touch his boots or skin when rendering assistance.

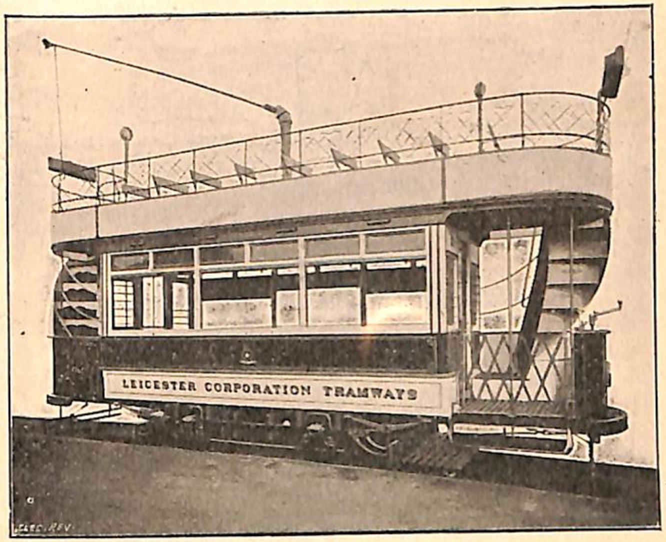
If unable to draw the person clear, the live wire should be pulled to the rail and rendered dead as previously described, or the power should at once be switched off at the nearest section box.

CHAPTER III.

ELECTRIC CARS.

Types of Cars.—Several different types of cars are in use in this country, some of the single-deck form, and others arranged to also seat passengers on the top.

FIG. 12.



SINGLE TRUCK CAR.

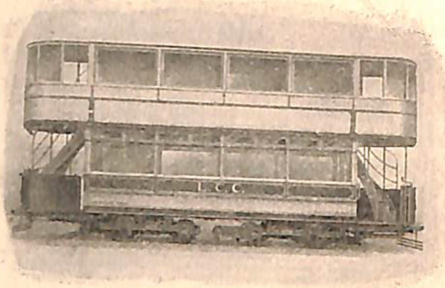
The double-deck form is most commonly used, and may be supported either on a single four-wheeled truck or on two separate bogie trucks.

An example of a single-truck double-deck car is given in Fig. 12.

Single-deck cars, of both open and closed types, are in use on some lines, and are carried on single or double trucks, according to their length.

A double-truck car with covered top is shown in Fig. 13.

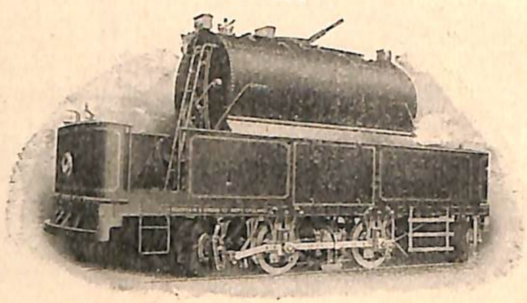
Fig. 13.



L.C.C. Car.

Special cars and vans are in use on some lines for conveying stores, sweeping the track, etc. In Fig 13A a car for sweeping and watering is shown, the water being sprinkled under pressure from an air-compressor.

Fig. 13A.



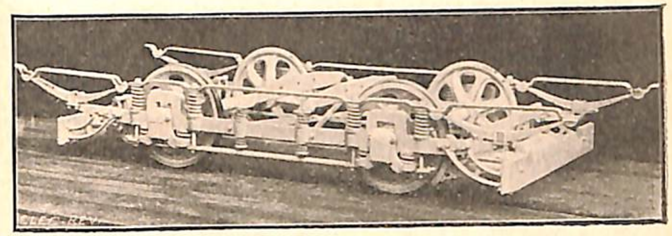
Mountain and Gibson's Sprinkler.

The body of an electric car is supported on the under truck by suitable springs, and simply serves to carry the motorman and passengers, all the propelling machinery being located in the truck below.

Single Trucks.—A "single" truck, of which a typical

example is shown in Fig. 14, is usually equipped with a motor on each axle, the motor being supported by the axle at one side and a strong cross beam at the other.

Fig. 14.



Brill Single Truck.

The cross beam is carried on springs on the side frame of the truck, and thus a flexible support is provided to the motors. The motor shafts are furnished with pinion wheels, which gear into large toothed wheels keyed to the car axles, and the power is transmitted in this way to the car wheels. Another form of single

Fig. 14A.

Radial Truck.

truck is shown in Fig 14A, and is provided with radial axle boxes to permit of the longer wheel base.

Maximum Traction Trucks.—A common type of double truck is given in Fig. 15, and is arranged to carry a single motor.

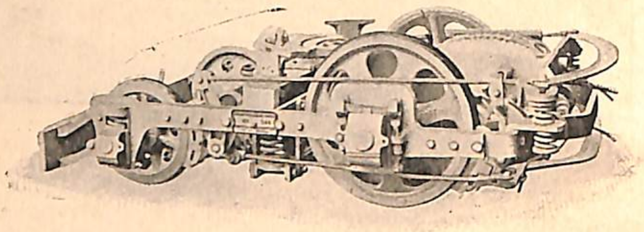
The motor drives the large wheels of the truck, and most of the weight of the car is carried on these wheels, to avoid slipping when starting.

The small wheels only carry sufficient load to keep them on the rails, and serve to support one end of the truck.

This form of truck is called the maximum-traction truck.

A maximum-traction truck fitted with magnetic brake and arranged with support for collecting plough for conduit lines is shown in Fig. 15A.

FIG. 15.

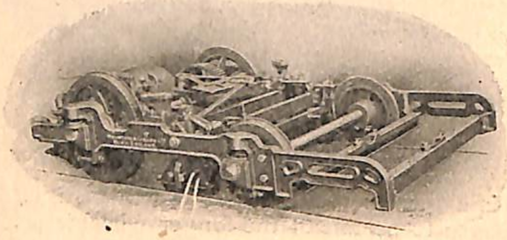


BRUSH MAX. TRACTION TRUCK.

Ordinary Double Trucks.—Another form of double truck is shown in Fig. 16, and is provided with equal-sized wheels.

This type of truck is employed when **four** motors are fitted to the car, one motor being carried on each axle, which it drives by the usual gearing.

FIG. 15A.

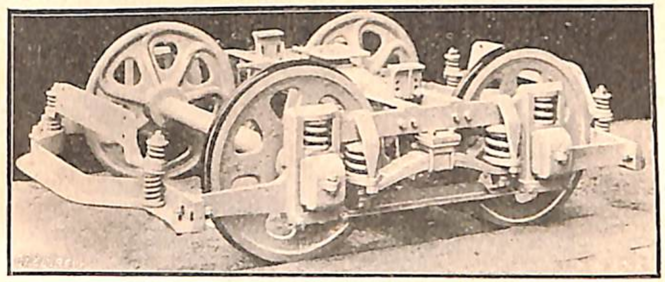


L.C.C. MAX. TRACTION TRUCK.

Car Motors.—The motors used on electric cars are exposed to very severe conditions of service, and must be completely enclosed and protected from all dirt and water.

Fig. 17 shows a car motor, and it will be noticed that it is practically iron-clad in construction, and is arranged to divide into an upper and a lower half, so that the armature and magnet coils can be examined or removed for repairs.

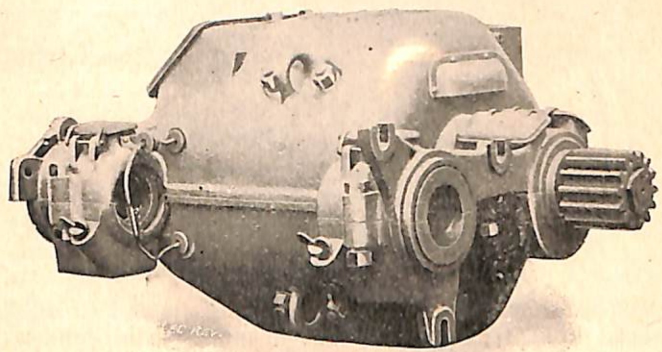
FIG. 16.



BRILL DOUBLE TRUCK.

The supply cables are taken in through insulating bushes at the sides, and an inspection cover is provided at the top to allow of the brushes and commutator being examined when necessary.

FIG. 17.



CAR MOTOR (CLOSED).

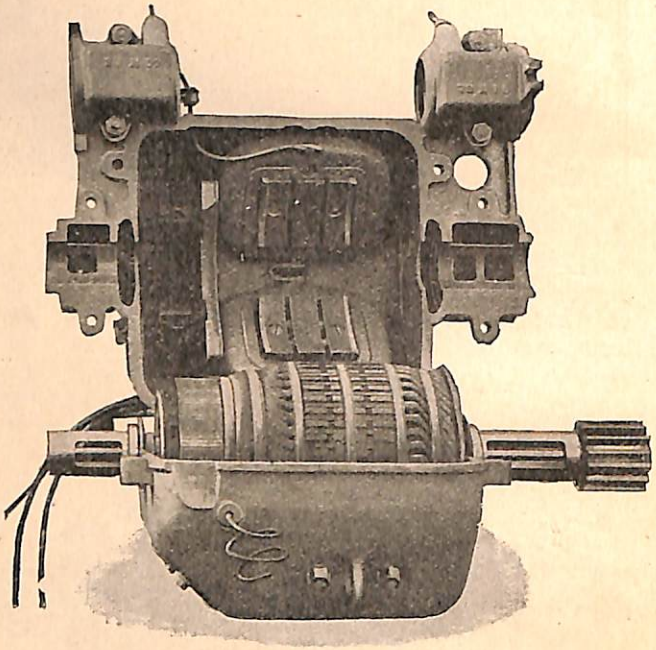
The armature shaft projects at one end and carries the small driving pinion.

The shaft runs in suitable bearings arranged at the ends of the motor case, and large oil-wells are fitted to keep it well lubricated when running.

The pinion gears into a large toothed wheel on the car axle, and both are protected from mud and grit by a cast-iron gear-case.

A motor with its case divided and the armature in position is shown in Fig. 18.

Fig. 18.



Car Motor (open).

The brush-holders are fixed in the upper half of the case immediately under the inspection lid, and are easily accessible from the inside of the car after lifting the traps in the floor.

Trolley Heads.—If a car is to be supplied with current from overhead wires it is necessary, of course, to provide it with a suitable pole and "trolley" wheel.

If the overhead conductor is suspended directly in line with the centre of the track a "centre-running" trolley, of the type shown in Fig. 19, is fixed at the end of the pole.

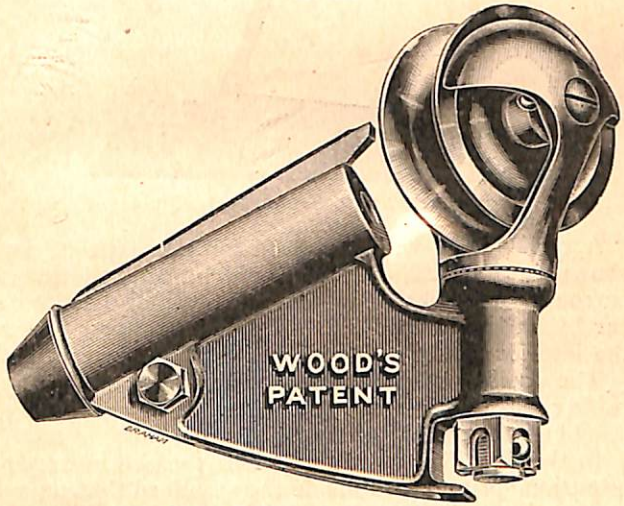
Fig. 19.

Centre-running Trolley Head.

Where the conductors are suspended at the side of the track the trolley head must be capable of swivelling in order to follow the path taken by the wire.

A "side-running" trolley is shown in Fig. 20.

Fig. 20.



Side-running Trolley Head.

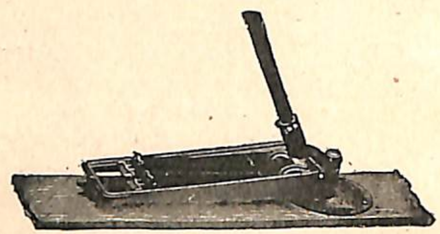
Collecting Ploughs and Skates.—If a car is to be supplied with power from conductors fixed in a conduit it is furnished with a collecting plough as described in Chapter II., and when the vehicle has to run on a "surface-contact" line a collecting skate to make contact with metal studs on the road is fixed on the under truck.

Single-Deck and Double-Deck Standards.—On single-deck cars the trolley pole is usually fixed directly on the roof, and by means of suitable springs is pressed upwards against the overhead conductor.

A form of trolley pole suitable for single deck cars is given in Fig. 21; the current collected by the wheel at the end travels down the metal pole, and by a cable attached to the bottom of it, down to the main switches on the car.

In the case of double-deck cars, where passengers are carried on the top, it is impossible to bring the current down the pole itself on account of the risk of shock to passengers.

FIG. 21.



TROLLEY FOR SINGLE-DECK CARS.

A trolley pole with standard for this type of car is shown in Fig. 22, where it will be noticed that the current is brought down from the trolley head to the car by an insulated cable, which passes down through the interior of the pole and supporting standard.

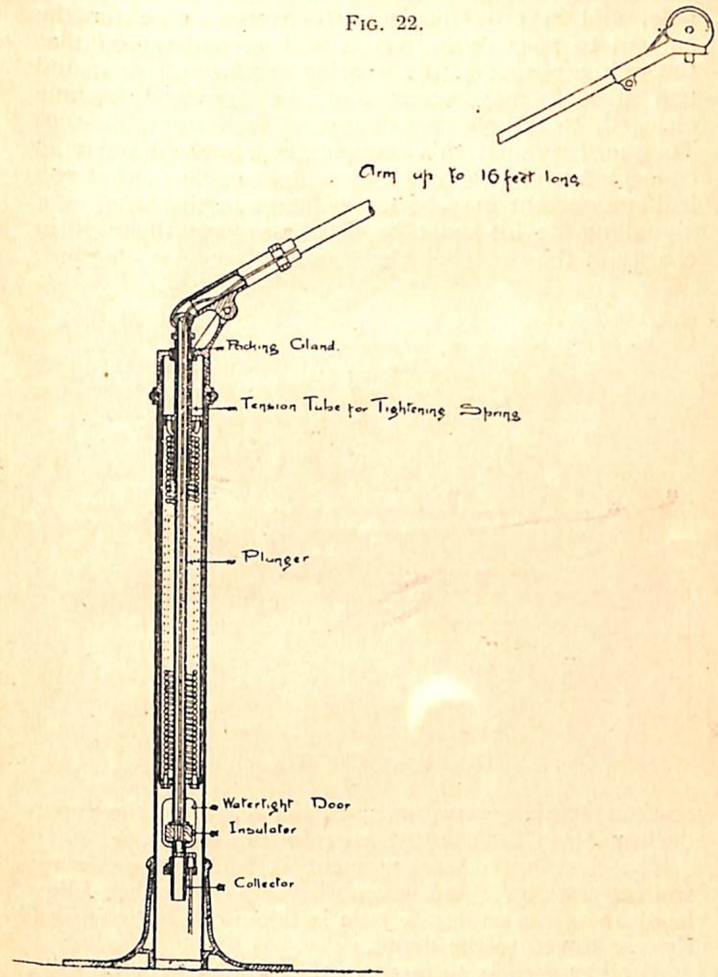
The trolley head is insulated from the pole by a rubber or mica sleeve, which prevents current from reaching the metal pole and standard.

In the type illustrated the pole is pressed upwards by a tension spring fitted inside the standard, but on some makes the springs are mounted on the outside.

The cable from the trolley head usually terminates at a socket at the bottom of the pole, which is free to swivel, so that the pole may be turned round and round in either direction without danger of twisting or breaking the cable.

In some cases the trolley standard is provided with a stop to prevent the pole from making more than one

FIG. 22.



TROLLEY FOR DOUBLE-DECK CARS.

turn round, and the cable from the trolley head passes down through the standard to the car without the intervention of a swivelling plug or socket.

"Leaks" on Trolley Standards.—Although great care is exercised in insulating the trolley head from the pole, and in providing a well-covered cable for the current to pass down, yet it will be understood that through exposure to the weather or through wear and tear a leak may occur and the standard become charged, to the obvious danger of passengers on top. To guard against this danger the standard must be connected to the car truck by a stout cable so that any leakage current may be taken direct to the rails, or a signalling device must be fitted to warn the men in charge of the car when the standard becomes charged,

Fig. 23.

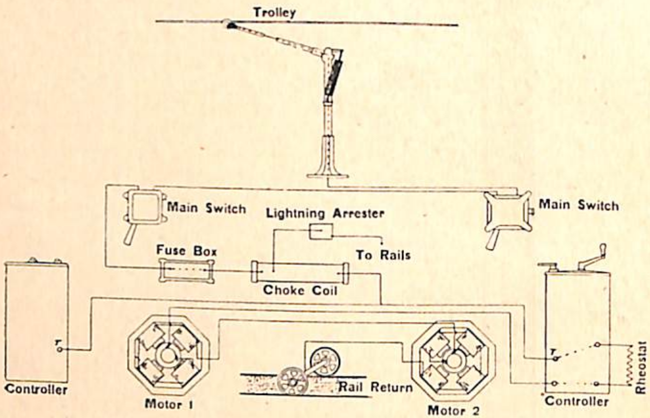


Diagram of Car Wiring.

so that they may remove the passengers from the upper deck and run the car to the depôt for repairs.

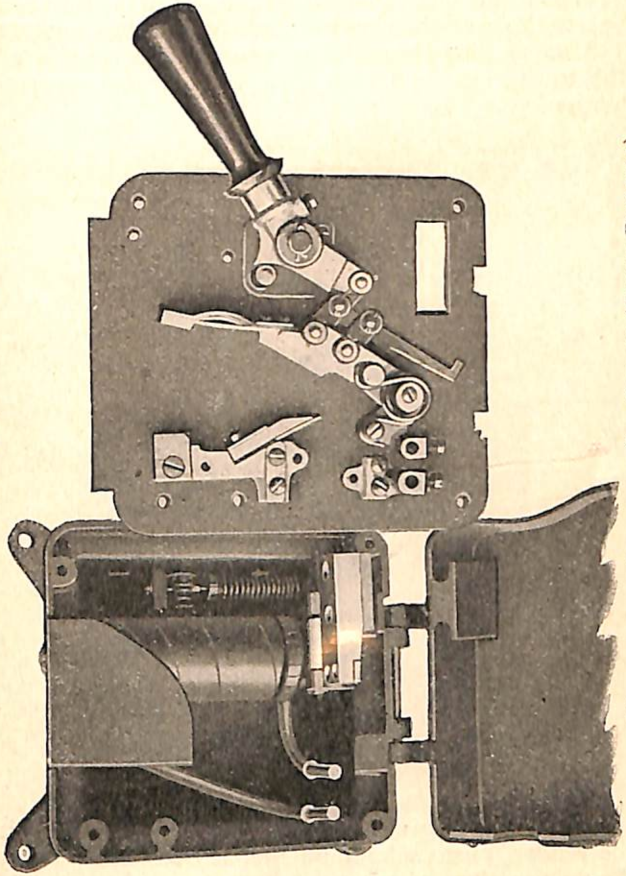
The first noted arrangement is followed on some tramway systems, and when a leak occurs at the trolley head or on the cable the pole is taken off the wire and the car towed to the depôt.

Another plan is to connect the standard to the rails through two incandescent lamps, which may be coloured red and fixed at the car platforms. When the standard becomes charged by leakage current the lamps glow brightly, thus attracting attention to the mishap.

Other devices are in use which cause a bell to ring or

a signal arm to be brought prominently into view, so that steps may be taken to prevent any person from coming into contact with the "live" trolley standard.

Fig. 24.



Westinghouse Automatic Car Switch (Front Removed).

Path of Current through Car.—In order to understand fully how the current passes through a car and arrives at the motors, the diagram, Fig. 23, should be examined.

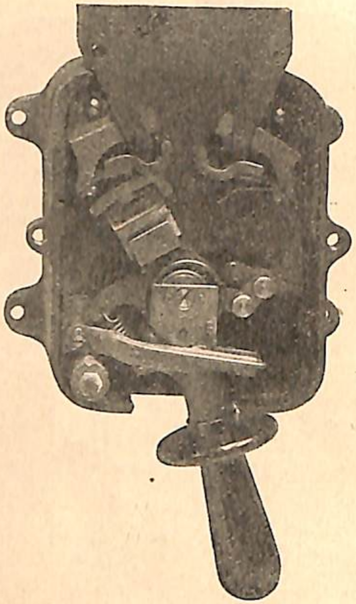
It will be seen that the current from the trolley head is led first to an **automatic switch** at one end of the car and afterwards to another **main switch** at the rear platform.

It then passes through a **safety fuse-block** and a **choking coil** before reaching the **controllers.**

When the controller handle is turned the current passes down to the **rheostat** and then to the car **motors.**

After passing through the motors the current reaches the track rails, and thus goes back to the generating station.

FIG. 25.



THOMSON-HOUSTON AUTOMATIC CAR SWITCH.

The diagram given follows the usual practice, but the reader must understand that it does not represent the only method in use.

For instance, on some cars the fuse-block is omitted, or the choke-coil may be introduced into the path of the current before the first main switch is reached.

Again, a car may be fitted with two automatic switches and the current passed through both in "series"; or these may be connected in "parallel," in

which case only one switch is used when the car is running, the one at the rear platform being left at the "off" position.

On cars running on conduit systems, the current, after passing through the motors, does not return to the power station by way of the rails, but goes back *viâ* the negative conductor in the conduit.

FIG. 26.

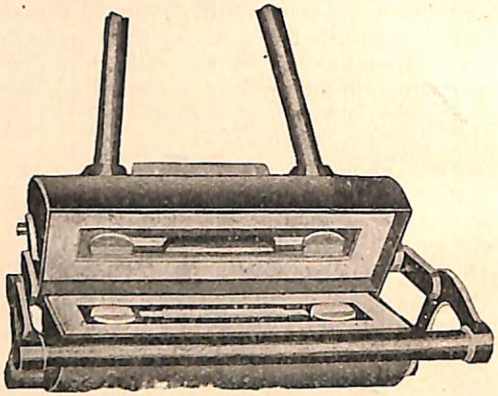
BRUSH CO.'S CANOPY SWITCH.

Main Switches.—The main switches which are generally fixed on the canopy over the motorman are for turning on and off the current, and may be automatic or non-automatic in action.

The **automatic** type of switches, of which examples are given in Figs. 24 and 25, are constructed so that they spring to the "off" position if an excessive flow of current passes through them.

They serve to protect the motors from dangerous overloads, and are usually adjusted so that it requires

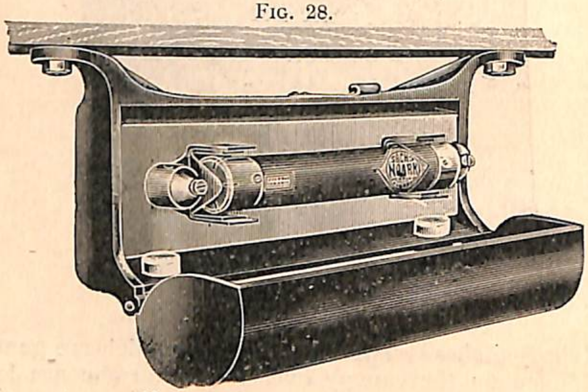
Fig. 27.



Westinghouse Fuse-block.

a considerable rush of current to trip them "off," such as would occur, for example, if the car was started too quickly, or if a leak occurred in a motor.

Fig. 28.



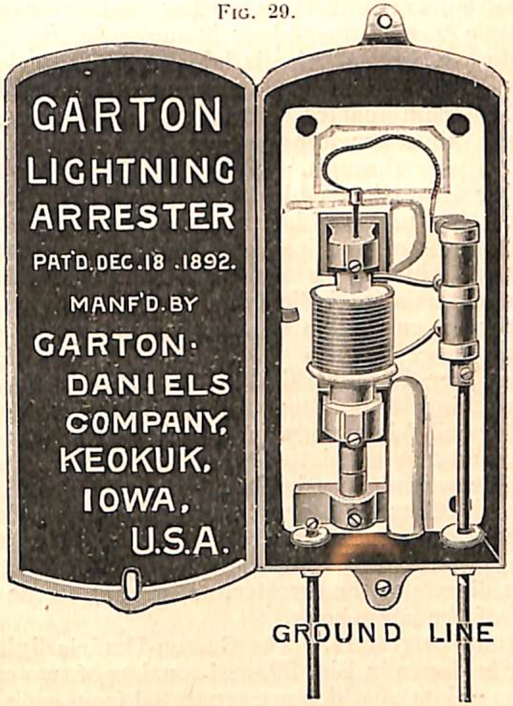
No-ark Enclosed Fuse-block.

Action of "Automatic" Switches.—Many different forms of automatic switches are in use, but they all work on the same general principle, the current passing through the switch being employed to excite a

magnet, and, at a certain strength, to knock the switch blade quickly to the "off" position.

Canopy Switch.—A main switch of the **non-automatic** type is shown in Fig. 26, and consists of a pivoted blade, which opens or closes a gap between two contact pieces, according to the position the operating handle is placed in.

Fig. 29.



Garton-Daniels' Lightning Arrester.

When switching off current with this switch the handle should be moved quickly to the "off" position to prevent the current from "arcing," and destroying the contacts.

Safety Fuse-blocks.—It is usual to fit a **fuse-block** on the car, and this device is employed to prevent an abnormal rush of current to the motors or a continuous overload being put on them.

Different forms of fuse-blocks are in use, all of which operate on the same principle.

The whole of the current used by the motors is passed through a short length of wire of a suitable size to carry the current required to propel the car. If the current exceeds this safe amount, the fuse-wire melts, thus breaking the circuit and stopping the supply of current until the wire has been renewed.

A simple form of fuse-block is shown in Fig. 27, in which the copper fuse-wire is laid into V-shaped brass blocks, and on closing the box contact is established with the main cables entering and leaving the apparatus, thus providing a complete circuit for the current to pass through.

Another form of fuse-block is shown in Fig. 28. In this type the fuse-wire is contained in a paper tube, which fits into spring clips in the box. When the fuse in the tube "blows," a thin wire on the outside also melts, and serves to indicate the fact. Several spare fuse-tubes are carried on the car for replacement when necessary.

Choking or Kicking Coils.—To prevent lightning from reaching the motors and causing damage, a "choking coil" is introduced into the path of the main current, and may consist of a number of turns of insulated cable wound on a bobbin.

This coil offers little or no resistance to the flow of the ordinary current from the trolley-wire, but it presents a great obstacle to the passage of lightning, which it diverts to the **arrester,** and thence to the earth by way of the car wheels.

Lightning Arresters.—The Garton-Daniels lightning arrester is shown in Fig. 29, and consists of two carbon rods, the points of which are separated from each other by a small air gap. The upper carbon rod can be drawn upwards by a magnet coil, and the gap between the carbons thus lengthened.

The ends of the magnet coil are connected to the bottom and middle terminals of a graphite rod, which serves as a resistance, and is mounted close to the carbons and coil in a suitable box.

When lightning enters the arrester by the line terminal, it passes up through the graphite rod, and thence by a flexible wire to the upper carbon rod, and sparks

across the small air gap to the lower carbon rod, which is connected to earth (*i.e.*, the car wheels).

As the ordinary power current will try to follow the lightning to earth, once an "arc" has been established between the carbon rods, it is necessary to pull the carbons apart and break the circuit. This is done automatically by a portion of the power current passing through the magnet coil, and causing the upper carbon to fly quickly upwards and widen the gap between the two rods.

B. T. H. Arrester.—The Thomson-Houston lightning arrester is somewhat similar to the one just described, except that in it the carbon rods are held permanently fixed at a short distance from each other, and if the power current jumps across the gap after the lightning, it is blown out by the action of a strong electro-magnet which destroys the arc.

Westinghouse Arrester.—In the Westinghouse arrester a block of hard wood is provided with charred grooves across which the lightning can travel to earth without trouble, but the comparatively low pressure trolley-current is unable to follow, owing to the high resistance offered to its passage by the carbonised channels on the wood block.

The wood block and the necessary terminals are enclosed in a small iron case for protection.

Controllers.—After the power current has passed through the main switches, and the safety devices which prevent any excessive flow of current or lightning from reaching the motors, it is taken to the controllers.

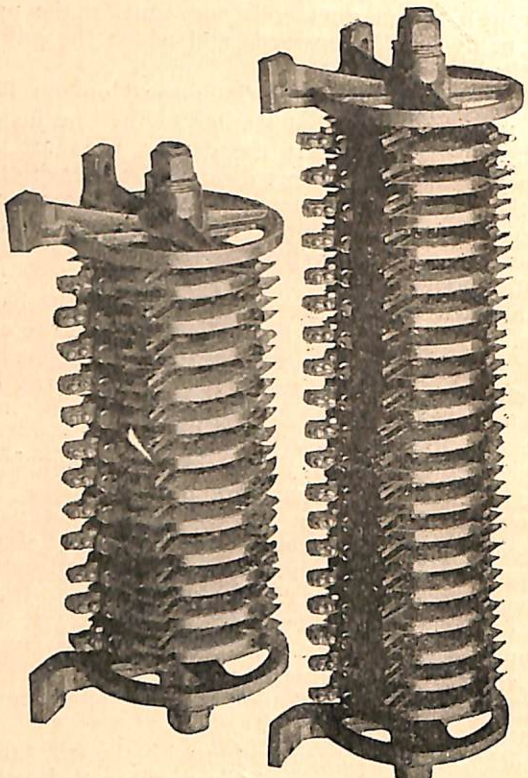
The controllers are mounted on the platforms, and are employed to regulate the speed of the car motors and change their direction of rotation.

In Chapter IV. several types of car controllers are illustrated and described.

Car Rheostats.—In connection with the controller it is necessary to provide a resistance coil or "rheostat" through which the current is passed, to reduce its pressure before reaching the motors.

In some forms of rheostat the current is passed through a thin metal tape wound in the form of a roll, each layer of tape being insulated from its neighbours by asbestos or mica, and a number of complete rolls are mounted on a suitable frame and are connected in series with each other. Fig. 30 is a complete resistance "barrel" of the class mentioned; usually two or more of these barrels are required on a car, and are mounted under the platforms or in ventilated compartments under the car seats.

Fig. 30.



Brush Co.'s Car Rheostat.

Terminals are arranged at each section of the rheostat, to which the cables from the controller may be connected.

As the rheostat becomes heated when current is passed through its coils, it must be constructed of fireproof materials, and must not be allowed to come

against the woodwork of the car or any material of an inflammable nature.

In some makes of rheostat the resistance material, instead of being coiled, is built up of zig-zag strips, and each strip connected in series with the next, the whole being mounted on and insulated from a suitable supporting frame.

Lighting Circuits.—The incandescent lamps on the

Fig. 31.

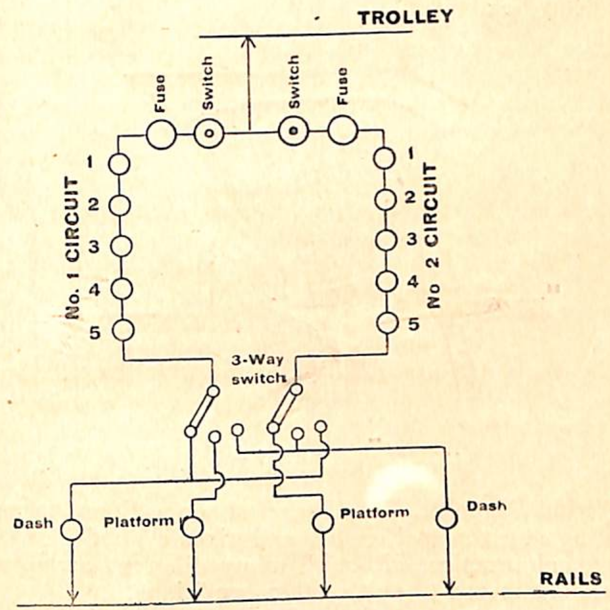


Diagram of Lighting Circuits.

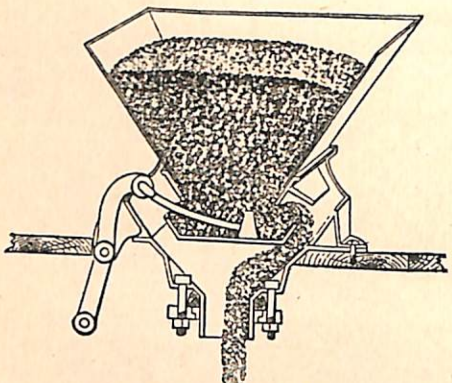
car are supplied with current from the trolley wire, a connection being made to the cable from the trolley head immediately after it enters the car.

By tapping off the lamp circuits at this point, they are rendered quite independent of the main motor circuit, and the lights may serve to indicate when the current is on or off the line.

It is usual to have two or three separate lamp circuits, so that the failure of one group of lights may not cause serious inconvenience. Each circuit is made up of five or six lamps connected in series, and is controlled by a small snap switch, and protected by a safety-fuse block.

Dash Lights.—As it is necessary to provide a front dash light whichever way the car may run, the lamp circuits must be arranged for this purpose, and it is also desirable that in the event of one circuit being disabled through the failure of one of the lamps, the dash light may be easily connected to a good circuit and delay be avoided.

FIG. 32.



INTERMITTENT SAND VALVE.

Wiring Diagram.—A diagram of connections for car lighting is given in Fig. 31, and gives a good idea of the usual practice, although many different arrangements are in use to suit certain conditions.

Tramcars are sometimes fitted with a red danger lamp at the rear. This lamp may be arranged to show the route colour on the return journey.

Electric Heaters.—To warm the car small electric heaters may be fitted inside and supplied from the trolley current.

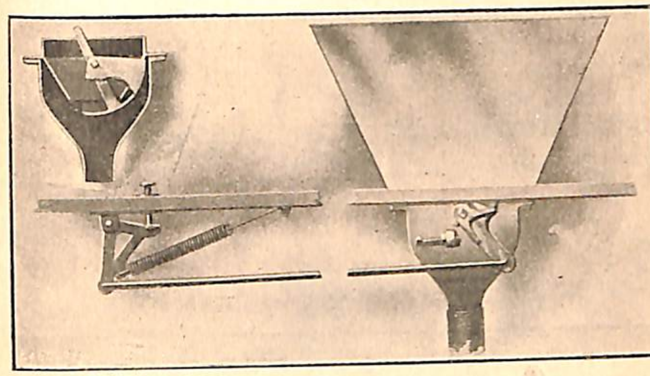
The current passes through coils of thin wire, which become hot, and by means of a switch the amount of heat generated may be varied as required by altering the amount of current going through the heaters.

In this country heaters are not much used, as the

climate is fairly temperate, and besides, heaters absorb a considerable amount of current and require a good deal of attention.

Signal Bells.—The signal bells on an electric car are worked by a small battery, generally fixed under the car seats.

FIG. 33.



CONTINUOUS SAND VALVE.

The current from the battery is led by insulated wires to " pushes " at convenient points; on the car conductor pressing the centre button of a push, contact is estab-

FIG. 34.

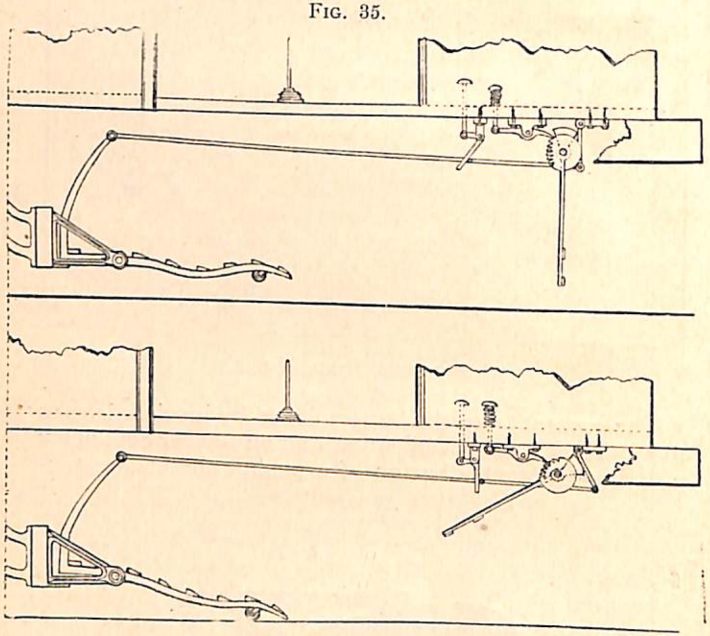
FOOT GONG.

lished between two springs inside, and the current is allowed to reach the signal bell at the end of the car and from thence to return to the battery.

If the bell is of the " trembler " type it will continue to ring so long as the button is pressed down. If of the " single-stroke " type the bell will give one sharp ring each time the button is pressed.

Sand Gear.—An important item in the car equipment is the apparatus for dropping dry sand on the track when quick stops are required, or when the rails are greasy and slippery. Various types of sanding-gear are in use, some of which provide a continuous flow of sand to the rails when in action, while others are constructed to allow only a small quantity to reach the rails at one application.

Fig. 35.



Trigger Life Guard.

In Fig. 32 is shown a sand-gear of the intermittent type, arranged to be operated by a foot-tramp on the car platform.

As will be seen, the sand is contained in a tapered box under the seat, and passes by a pipe down to the rail when the valve is opened by the motorman.

A sand-valve of the constant-flow type is shown in Fig. 33. By slightly opening the valve a small flow of sand is allowed to reach the wheels, and in emergencies

the valve can be opened full to allow plenty of sand to fall and assist in stopping the car. Instead of a foot-tramp a small hand-lever is sometimes fitted to operate the sand gear, or a trigger may be fitted to the dash to be moved by the motorman's knee.

On some cars fitted with air-brakes, arrangements are made to blow the sand under the car wheels for emergency stops.

Dry Sand.—As only small openings are provided in the sand-valve, it is necessary to use only dry riddled sand, and also to prevent paper or sticks from getting into the sand-box when filling it; otherwise delay and trouble may be caused by the valve becoming choked and refusing to act when required.

Fig. 36.

Destination Indicator.

Foot-gongs.—To warn people of the car's approach a gong is fitted under the platform, and is sounded by means of a foot-tramp.

A car-gong is shown in Fig. 34, where it will be noticed that on pressing down the tramp a heavy clapper is thrown against the rim of the iron gong.

The foot-tramp must not be too short, or it may fail to sound the gong; nor must it be too long, as then it would hold the clapper hard against the gong and prevent it from sounding properly.

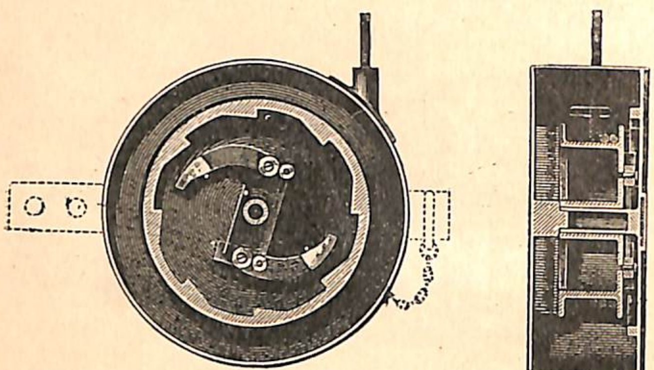
Life Guards.—Electric tramcars are always fitted with "life guards" to push aside or pick up any person who may fall on the track in front of the car.

Many different forms of guards are in use on the various tramway systems. On some cars strong wire netting is used round the front of the truck, or slanting boards are fixed so that they tend to push any obstacle to the side of the line clear of the car wheels.

Another type of guard extensively used is depicted in Fig. 35, and as can be seen, is arranged with a swinging gate or "trigger" in front, against which the obstacle first strikes.

The trigger, when pushed backwards, releases the flat guard behind it, which is pulled down to the surface of the roadway by a strong spring, and thus scoops up any person or obstacle that may have fallen in front.

FIG. 37.



TROLLEY CATCHER.

Destination Indicators.—To indicate the destination of the car a board or screen is generally fitted at each end and bears the name of the place to which the car is proceeding.

Where cars have to run on several different routes, a convenient form of destination indicator is one having the names of the different termini painted on a linen roller or blind, and arranged so that any name may be brought to view by turning a small crank handle.

This form of indicator is shown in Fig. 36, and has fixed inside it a lamp to illuminate the screen at night.

Trolley Catchers.—As considerable damage is often caused by the trolley jumping off the overhead wire when the car is running, several automatic devices

have been invented to catch the trolley cord and prevent the pole from flying upward when the wheel jumps off.

A type of trolley catcher for "centre-running" poles is shown in Fig. 37, and consists of a small drum on which the cord from the pole is wound.

The cord is kept taut by means of a spring inside the drum, but if the pole should come off and try to spring up the cord is at once gripped and remains caught until released by the motorman or conductor.

CHAPTER IV.

CONTROLLERS.

Car Controllers.—To regulate the speed of a car, either forward or backward, a " controller " is fitted on each platform, and the current from the line is taken to these after passing through the main switches and the usual overload devices.

The controller is fitted with two removable handles; a small one which is moved forward or back according to the direction in which the car is to run, and a larger one by which the speed of the motors is regulated.

Handles Interlocked.—The large and small handles are " interlocked," and can only be operated in a certain correct fashion.

They can be removed only when the controller is standing at " off " position.

Single Motor Controllers.—When a single motor is fitted to the car, its speed is varied by a simple controller which sends the power through a rheostat to begin with, and then gradually cuts the rheostat out of circuit as the handle is moved round to " full power."

To reverse the car, a small lever is pulled back and operates a switch inside the controller which changes the direction of the current through the motor armature and causes it to run in the opposite direction.

This simple " rheostatic " method of controlling the speed is very wasteful in action, as a large proportion of the power taken from the line is lost in the resistance except when running at " full power."

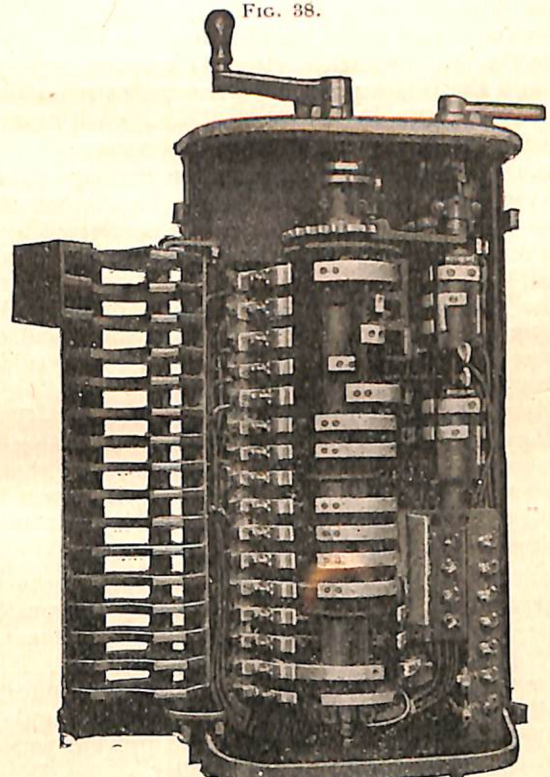
Series-parallel Controllers.—When two motors are fitted to the car, the rheostatic control is abandoned and the more economical " series-parallel " method is adopted instead.

With this method the controller is arranged to connect the motors in **series** when low speeds are required, and for high speeds it connects the motors in **parallel**.

When connected in series the current passes first through one motor and then through the other to the rails. When connected in parallel the current divides and passes through each motor separately to the rails.

By connecting the motors in series when starting they each absorb half of the pressure of the supply cur-

FIG. 38.



WESTINGHOUSE NO. 90 CONTROLLER.

rent, and less current is taken to get the car into motion than if the motors were arranged in parallel.

When the controller handle is brought to the first series " notch " the power is passed through a resistance coil to reduce the pressure before reaching the motors and effect an easy start.

As the controller handle is moved round, the resistance is gradually switched out until, on "full series" notch, it is dispensed with altogether, and the current reaches the motors without obstruction.

The "full series" notch may therefore be used for any length of time, as no waste is taking place.

On this notch the car runs at about half speed.

To obtain higher speeds the controller handle must be moved round to the parallel notches.

On the first parallel position the current is again sent through the resistance, and afterwards passes through the two motors in "parallel," *i.e.*, each receives a separate and independent supply of power.

As the controller handle is taken further round, the resistance is cut out by easy stages, and when the full power notch is reached the current is allowed to reach each motor direct, and the car runs up to its maximum speed.

The "full parallel" notch can be used for any length of time without objection, as the rheostat is cut out of action, and all the power is usefully employed in the motors to propel the car.

Advantages of "Series-Parallel" Method.—The advantage of the "series-parallel" method of speed control over the simple rheostat system is that **two** economical speeds are obtained—"half power" and "full power," and also a smaller rheostat may be employed.

Four-Motor Controllers.—When four motors are fitted on the car they are generally connected in "pairs," and the controller is arranged to connect the two "pairs" in series for starting.

For the higher speeds the "pairs" are connected in parallel, and, of course, on "full series" and "full parallel" the rheostat is cut out to prevent waste.

Westinghouse No. 90 Controller.—The Westinghouse No. 90 series-parallel controller is shown in Fig. 38; it is arranged with seven **power** and five **brake** positions.

The large handle turns the main contact drum and regulates the supply of current to the motors, and the same handle regulates the action of the electric "brake."

The small handle is for reversing the direction of running.

For safety the handles are interlocked so that the small one cannot be removed unless the power handle

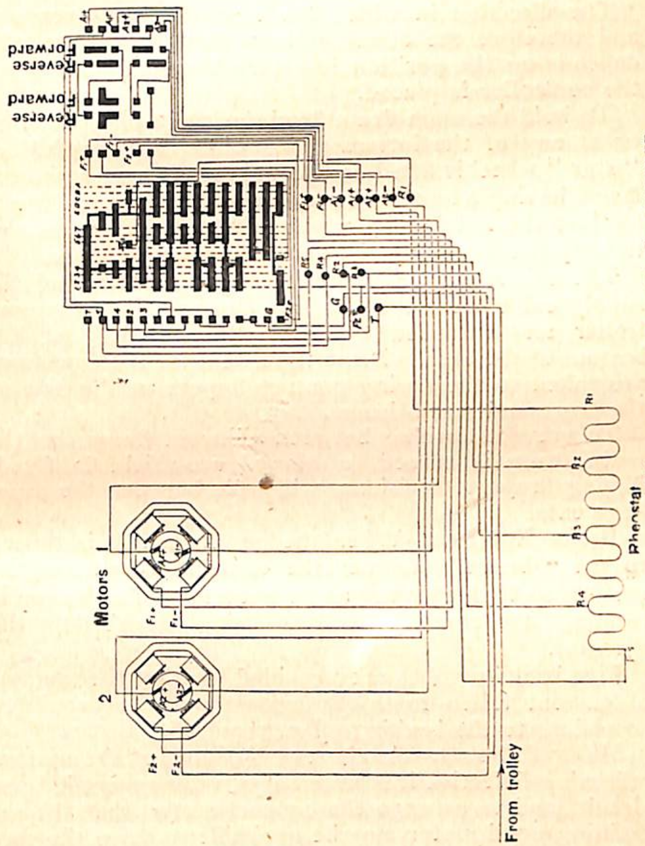


FIG. 39.—DIAGRAM OF WESTINGHOUSE No. 90 CONTROLLER.

is at "off," nor can the large handle be moved round unless the small lever is put forward or back.

When the power drum is turned round it makes contact with several "wipers" or "fingers" arranged at the side, and thus establishes the connections necessary for the different speeds.

By means of the mechanical devices under the top cover the two small drums at the side are turned round when the main drum is turned, and these make connection with side fingers, so that the current passes through the car motors in a certain direction.

The direction in which these small drums revolve, and therefore the direction in which the car travels, depends on the position in which the small handle of the controller is placed.

To hold the main drum firmly at the "off" position or at any of the intermediate points, a "notch" or "star" wheel is fitted on the main shaft, and a pivoted lever, having a small roller at one end, is pressed firmly against the notches by a powerful spring, and serves to keep the power handle at the various positions.

The cables from the motors and rheostat, and the supply cable from the line, are brought into the controller and attached to brass "terminals" at the bottom of the case. From these terminals connections are taken to the spring contact fingers at the side of the large and small drums.

To prevent flashing between adjacent fingers as the main drum is turned, a hinged arc-shield is fitted, having fireproof divisions, which lie between the drum segments.

Brake Notches.—When the power handle is turned to the "brake" notches the controller connects the motors so that they act as generators while the car is running, the current produced being absorbed in the rheostat.

Five brake notches are provided, so that the amount of current taken from the motors may be regulated according to the braking effect required.

Motor Cut-outs.—In the event of one of the motors becoming defective it is necessary to disconnect it from circuit, and to arrange the connections so that the remaining good motor may be available to drive the car.

To do this, one of the small drums must be turned round to the right by pulling out the small brass knob attached to it.

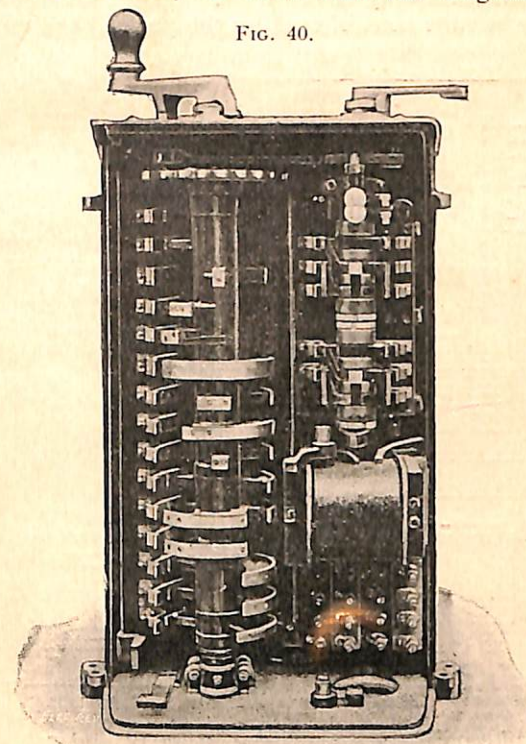
When a motor "cut-out" has been moved over, a small catch is pushed out and prevents the power drum from turning past "full-series" notch, and the car runs at its top speed on this point.

Diagram of Connections.—The complete connections for a No. 90 controller are given in Fig. 39.

The controller drums are shown as if they were flattened out, and the positions which the drums take when on the various notches are indicated by dotted lines, having the notch numbers marked at the top.

The correct way to work from the diagram is to

Fig. 40.



Westinghouse No. 210 Controller (open).

imagine all the fingers to be moved over to the dotted line under consideration, and then trace the path of the current along the lines and segments.

It will be noted that the main drum is in six parts, each insulated from its neighbour and from the shaft.

When considering the connections made on the parallel notches it should be remembered that the current has to divide to both motors, and afterwards get to the rails (*i.e.*, ground).

The "T" finger is not in contact on any of the brake positions, as no current is then required from the line.

Finger R1 makes contact on 1st brake notch.

The two bottom fingers are both in contact on all brake points, but only one of these fingers should make contact when the controller is on the power positions.

FIG. 41.

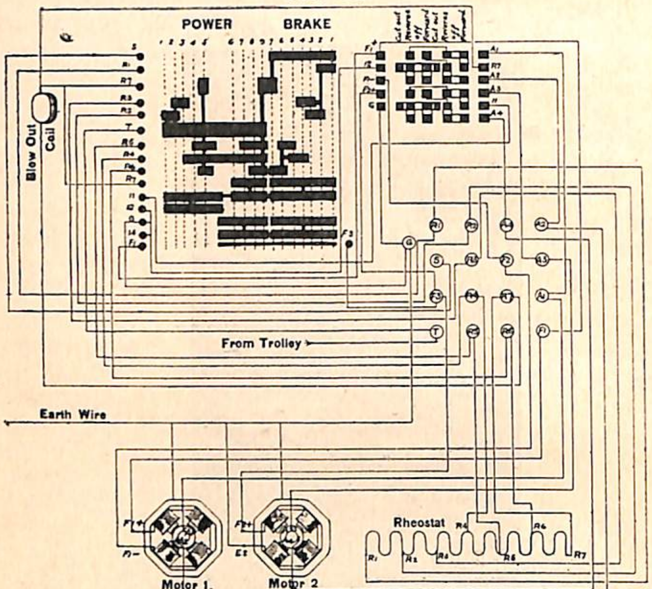


DIAGRAM OF WESTINGHOUSE NO. 210 CONTROLLER.

The brake points are marked A, B, C, D, and E.

Connections Made.—The following are the connections made by this controller on the different notches :

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.

FIG. 41A.

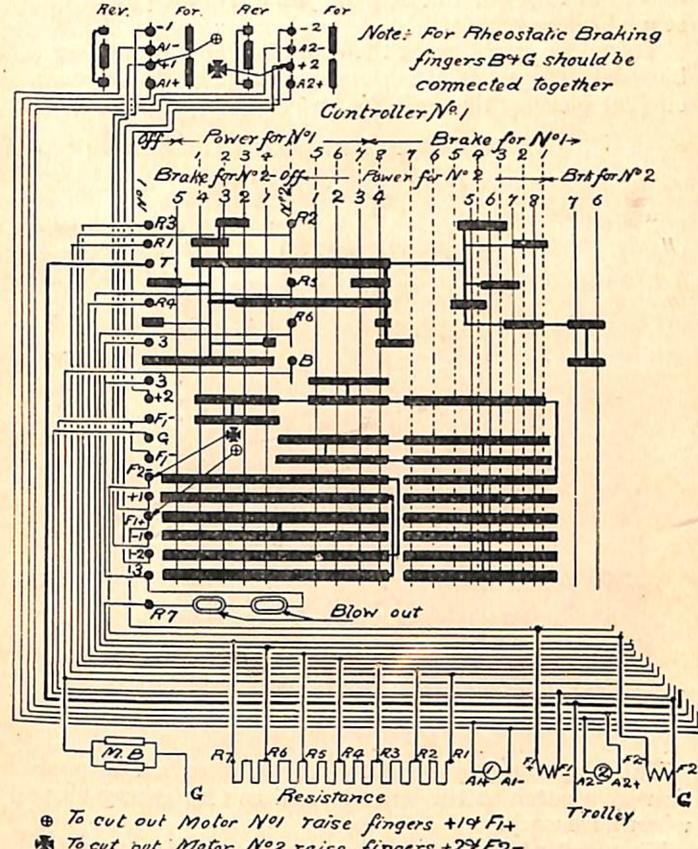


DIAGRAM OF WESTINGHOUSE NO. T1 C CONTROLLER.

Westinghouse No. 90M Controller.—This controller is similar in general construction to the No. 90, but is arranged with eight power notches (five series and three parallel) and with seven brake notches. The increase