TRAMWAY CARS AND EQUIPMENT

CONSTRUCTION OF CARS

CAR BODIES

SINGLE-DECK CARS

1. Types of Cars.—The cars used for conveying passengers on tramways may be **single-deck** or **double-deck cars**, according to whether seating accommodation is required on one floor, immediately accessible from the ground level, or on two floors or decks, the upper one of which is reached by means of stairs. Single-deck cars are not used very much in the British Isles or in France, but otherwise they are the standard nearly all over the world. Where single-deck cars are used exclusively, the heavy traffic of the morning and evening and of holiday times is carried by using *trailer cars*, which are drawn behind the ordinary *motor cars*, as they have no means of independent propulsion. Motor cars are independently driven units, each being complete with motors, controlling devices, and means of collecting current from the trolley wire or working conductor. In the British Isles the Board of Trade regulations forbid the use of trailer cars, so that the cars must be built for the maximum number of passengers that are to be carried at the busiest hours, at the expense of propelling a certain amount of unnecessary weight at the times of lightest traffic. Cars mounted on two trucks are known as **double-truck,**

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or **bogie, cars**; those mounted on a single truck and running on four wheels are known as **single-truck cars.** The motors which drive the cars are invariably mounted on the trucks between the car wheels.

2. **Arrangement of Single-Deck Cars.**—The use of single-deck cars in the British Isles is mainly confined to special purposes. When of the *open type*, that is, without enclosing panels and windows at the sides, they are used for summer excursion traffic at seaside resorts. The *semi-convertible car*, which has side panels, and windows which can be opened or closed as desired, is also used. Passengers can enter or leave the open-type car by stepping on or off at any point on either side, but the semi-convertible car has doors only at the ends. Single-deck cars are also used on certain routes where railway or other bridges are too low to allow the use of double-deck cars, and also in shallow subways immediately below the street level, as in the case of the London County Council subway underneath Aldwych and Kingsway.

3. **Single-Deck Steel Car.**—The ordinary tramway car for use on the surface usually has a wooden body, or superstructure, built on a steel *underframe*, which is supported on the truck or trucks. The shallow subway cars of the London County Council are built entirely of steel, in order to prevent danger from fire. One of the cars, built by the United Electric Car Company, is shown in Fig. 1 (*a*), (*b*), and (*c*), which gives side and end elevations and plan of the car body, respectively. The underframe consists of longitudinal sole bars *a*, formed of rolled-steel angles, which support cross-joists *b* and terminate in channel bars *c* at the end of the car body. The double-channel pillars *d* form the framework of the car body, which is stiffened by the diagonals *e*. The underframe is stiffened by a truss composed of the vertical struts *f* and tie-rods *g*. The sides of the car are completely closed by panelling and glass, the passengers entering and leaving by doors at the ends.

4. The driver's and conductor's platforms *h* are carried on extensions from the sole bars *a*, and access to the platforms is gained by the steps *i*. The curved dash *j* has a glazed opening *k*

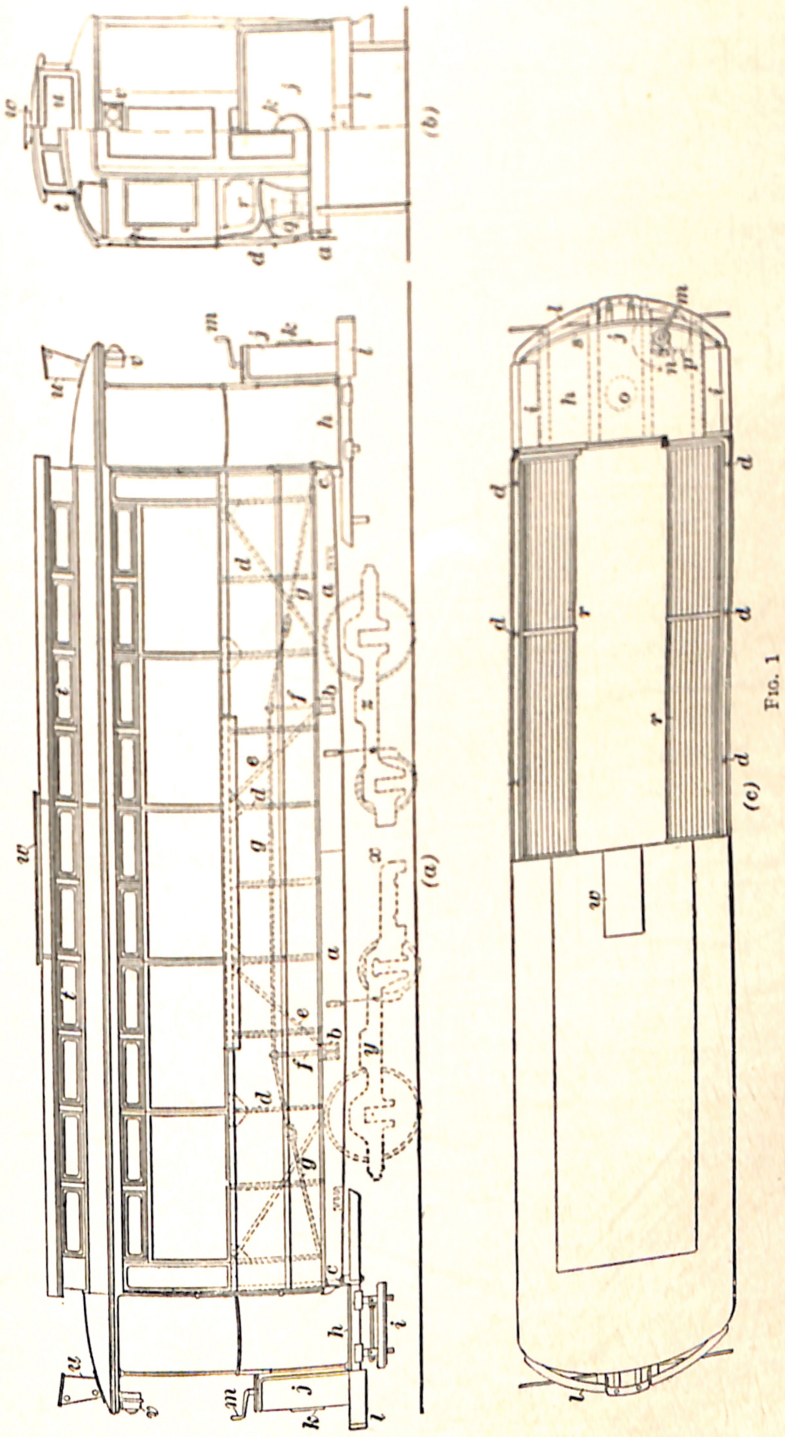


FIG. 1

for a head-light, while collision fenders *l* serve to minimize injury to the car in case of accident. On each platform are the brake handle *m*, pedal *n* for sounding the signal gong *o*, and pedal *p* for sanding the rails, the sand being stored in a box *q* under the car seat *r*. The electric controller by which the car is operated is placed on each platform at *s*. The roof of the car is of the clerestory type, with glazed clerestory *t*. Route indicators *u* and signal-lamp indicators *v* show the destination and route of the car. On the top of the clerestory is the trolley board or plate *w*, on which the trolley standard is mounted if current is derived

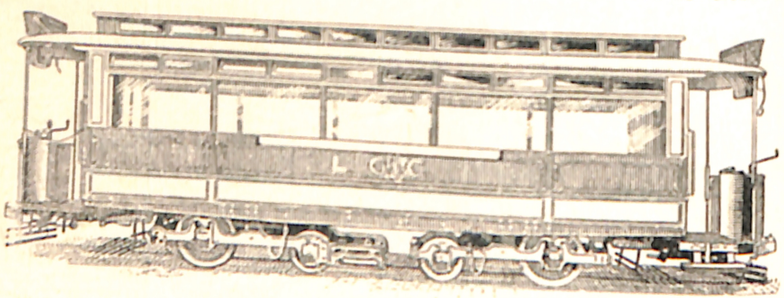


FIG. 2

from an overhead trolley wire. The car shown, however, is worked on the conduit system, and each car carries a plough on the extension *x* of one truck *y*; the other truck *z* is built without any extension. The total length of the car over collision fenders is 33 feet 6 inches, the width over the roof is 6 feet 10 inches, and the height from the rail head to the top of the trolley plate is 11 feet. The total *wheel base*, or distance between centres of outermost wheels, is 14 feet 6 inches. The seats of this car are longitudinal and accommodate 36 passengers. The appearance of the complete car is shown in Fig. 2.

DOUBLE-DECK CARS

5. Construction of Double-Deck Car. — A typical British double-deck car, built by the United Electric Car Company for the London United Electric Tramways, is shown in Fig. 3, which consists of a side elevation (*a*) and a plan (*b*). A vertical cross-section is given in Fig. 4, which is drawn to a larger scale than

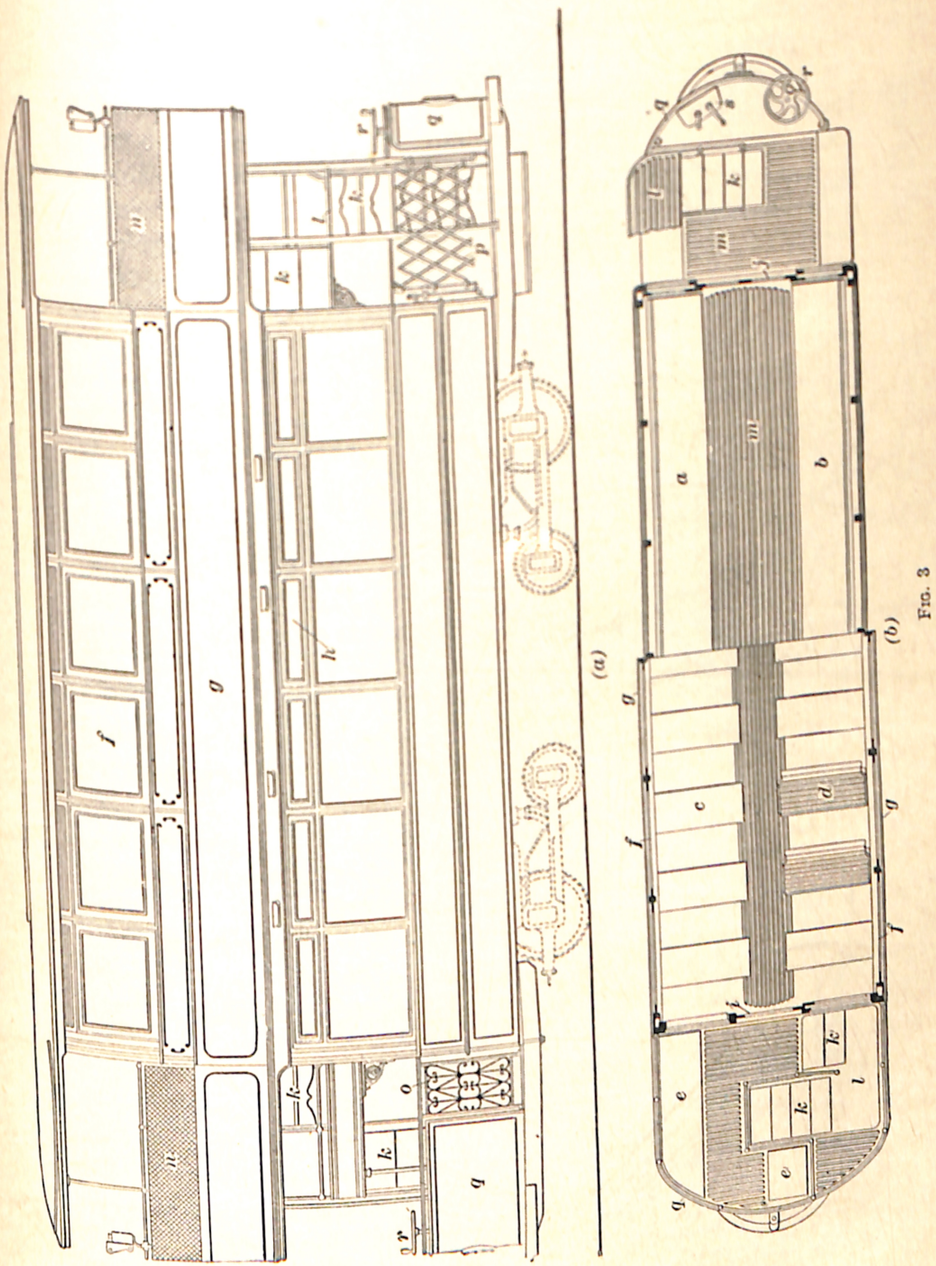


FIG. 3

Fig. 3 in order to show the constructional details; the lettering is the same for both illustrations. In the type of car illustrated, seating accommodation is provided for 74 passengers, 30 on the lower and 44 on the upper floor, or deck. The seats *a*, *b* on the lower floor are longitudinal, while those *c*, *d* on the upper are cross-seats with swing backs, so that passengers can face either the front or rear; in addition, four passengers can be accommodated at each end on the outside fixed seats *e*. On the older types of double-deck cars, the top seats were open and no protection from the weather was afforded to the passengers travelling on the outside of the car. The modern tendency is to build a roof over the top seats, and, by carrying the sides up to the roof, to enclose the top deck as well as the lower deck by means of panelling and windows. The upper windows *f* are in this case arranged to open, by lowering them into a space provided behind the top-deck panelling *g*. The small windows *h* of the lower deck can be opened for ventilation, but the main windows are fixed. Sometimes, however, all the side windows of a car are arranged

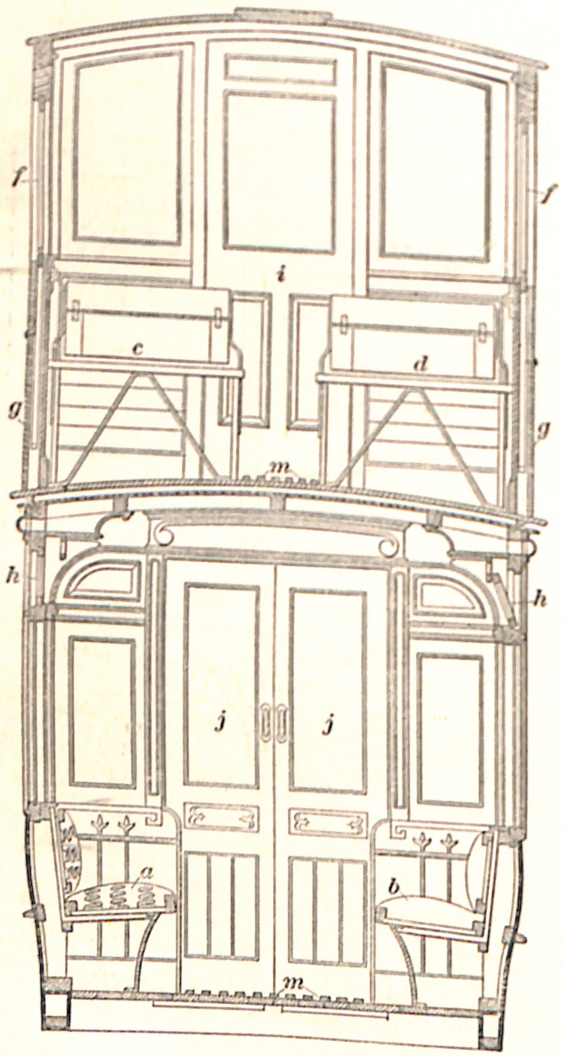


Fig. 4

so that they can be thrown open in hot weather. Single sliding doors *i* are provided at the ends of the car on the upper deck, and double sliding doors *j* below. Stairways *k* are built to give access to the upper deck at both ends of the car. They are built as left- and right-handed spirals and, as in the present instance, in two straight portions, with a small intermediate platform *l* between them. The car floors and platforms are protected with wearing strips, or slats, *m*; by renewing the slats from time to time, the solid floor is kept sound. The upper platforms are

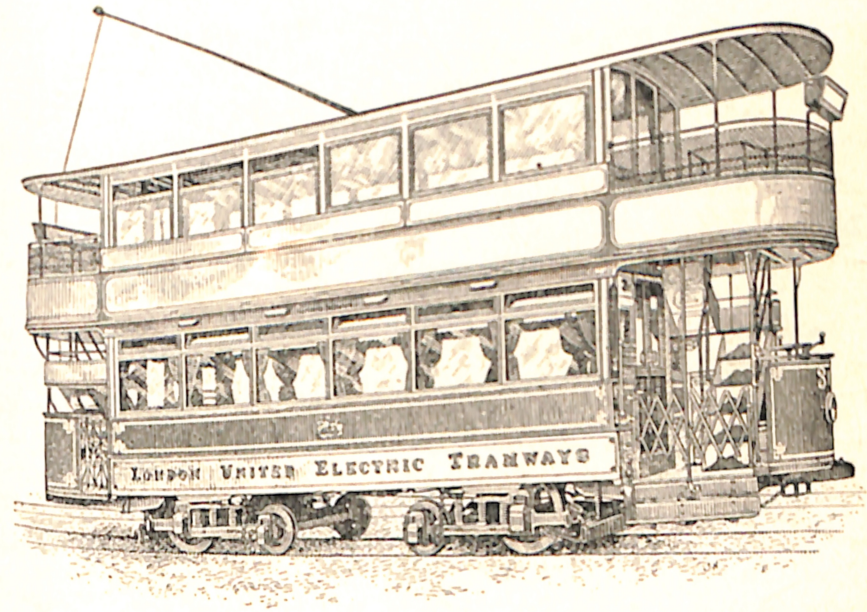


Fig. 5

surrounded by metal screens *n*, and each lower platform can be closed by a swinging gate *o* and a collapsible gate *p*. When driving the car, the driver, or motorman, stands between the stairway and the dash *q*, where he has room to operate the brake hand wheel *r* and controller *s*. The total length of the car over the collision fenders is 34 feet 7½ inches, the maximum width 7 feet 2 inches, and the height 15 feet 10 inches. The general appearance of a double-deck car of the type illustrated in Figs. 3 and 4 is shown in Fig. 5, from which the general arrangement of the car can easily be understood.

TRUCKS

TYPES OF TRUCKS

6. Properties of Trucks.—The functions of a car truck are to form a spring support for the car body and a frame for the driving motors and wheels. The motors must be at least partly spring-borne, but the motor-bearing springs must be distinct from the car springs. A truck must be easy-riding and as simple as possible; also, the wearing parts must be easily replaced and few in number. Either one or two trucks may be used on a car, but each truck must be self-contained, the wheels and axles, motors, driving gear, and brakes all being mounted in one independent framework. One *single truck* is used on a single-truck car, and two *double trucks* on a double-truck car. As each truck has four wheels, a single-truck car has four wheels only, while the double-truck car has eight wheels altogether. The choice between single and double trucks depends on the length of car to be supported. The total wheel base must be long enough to support the car body without excessive oscillation, but the rigid wheel base must not be so long that the wheels will bind in the rail grooves at curves. Single trucks, with a wheel base usually of 6 feet, are used for car bodies up to about 28 feet in length, and double trucks, with a wheel base of 4 feet or 4 feet 6 inches each, for all longer cars.

7. Standard Four-Wheeled Single Truck.—The construction of a **four-wheeled single truck,** made by Hurst, Nelson, and Company, is shown in Fig. 6 (*a*), (*b*), and (*c*), which are side elevation, plan, and end elevation of the truck, respectively. The truck is designed for the standard rail gauge of 4 feet $8\frac{1}{2}$ inches, and has a wheel base of 6 feet and wheels of $31\frac{3}{4}$ inches in diameter. The main frame of the truck, consisting of the side bars *a* and end cross-bars *b*, is made of steel, forged solid. The underframe of the car body is bolted to the top plates *c* of the truck, so that the weight is supported and transmitted to the side bars *a* by four helical springs *d* and two elliptic springs *e* on each side of the truck. The helical springs *d* take the principal dead weight of the

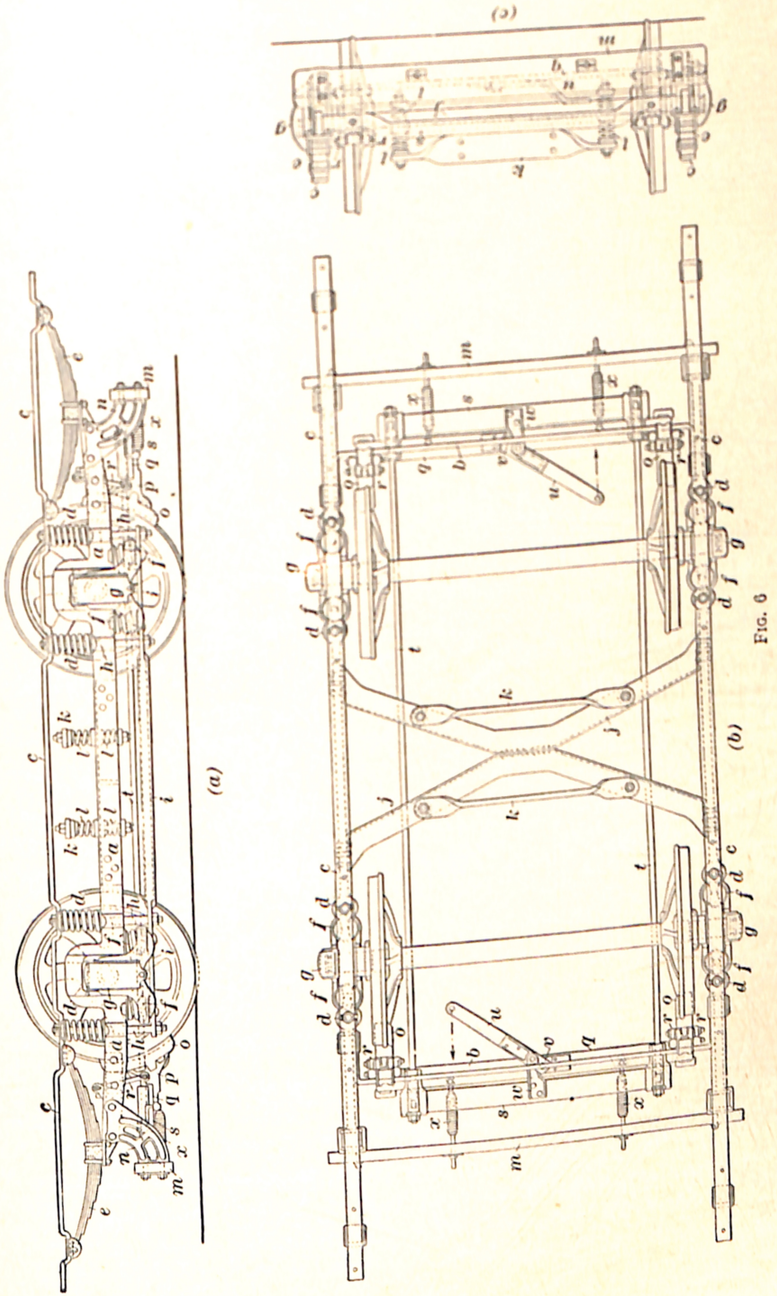


FIG. 6

car, while the displacement of the load during the starting and stopping of the car is taken by the elliptic springs, and oscillation of the car is to a large extent prevented. The main side bars *a* of the truck, which carry the whole weight of the car body and truck, rest on the helical axle-box springs *f*, of which there are four on each side of the truck. These springs *f* rest on wings, or brackets, carried out from the sides of the axle boxes *g*, which are themselves hung direct on the car axles, outside the wheels, and are free to slide vertically in guides formed by the vertical limbs of the side bars at these points. The whole side frame of the truck is kept stiff and square by taking the spring posts *h* of the body springs *d* through suitable holes in the side bars and by staying the spring posts together by means of the stay *i*. To prevent vibration and noise, all the spring seats are padded with felt, which is protected by wrought-iron washers.

8. The side bars *a* of the truck frame, Fig. 6, are stiffened laterally by the diagonal brace bars *j*, from which the motor supports *k* are spring-supported; the double motor springs *l* cushion both the up and the down movements of the motor supports *k*. On a single-truck car two driving motors are used, one motor driving on to each axle. The weight of each motor is divided between the axle and motor support from which it hangs. Pilot boards *m* are supported from the side bars at each end of the truck by means of pilot brackets, or braces, *n*; when life guards are used on the car, they are generally attached to the pilot board. The wheel brakes, together with the *brake rigging* by which they are operated, are usually built and supplied by the makers of the trucks. The brake shoes, or blocks, *o* are held in *shoe holders*, or *block carriers*, *p* fixed to the ends of the transverse bars *q*, which are known as the *brake beams*. These brake beams are hung from the truck end bars *b* by means of the brake-block hangers or swinging links *r*. A rectangular frame, formed of the equalizer bars *s* and equalizer rods *t*, rests on the brake beams, and slides on them when the brakes are applied by pulling either brake lever *u* in the direction of the arrows shown in view (*b*). Each brake lever is pivoted to a fixed point *v* on the brake beam, and also to a fulcrum *w* carried by

the equalizer bar *s*. The brake blocks are kept away from the wheels, except when the brakes are intentionally applied, by means of the brake-release springs *x*.

9. **Compensating Single Truck.**—With the ordinary arrangement of springs on the standard four-wheel truck, as shown in Fig. 6, all the springs are in action at all times, whether the truck and car are lightly or heavily loaded. Therefore, if the springs are sufficiently flexible to give easy riding when the load is light, the deflection of the springs will be large when the load is extremely heavy, especially with a double-deck car, and the ability of the springs to take up vibration and to prevent oscillation of the car under such conditions will be greatly diminished. The Preston **compensating truck,** shown in Fig. 7, has been designed to meet heavy-service conditions and to obtain greater freedom from oscillation under all possible conditions of load. This is brought about by the provision of auxiliary springs which only come into action when the truck is heavily loaded. View (*a*) shows a side elevation and view (*b*) a plan of the truck, which has a wheel base of 6 feet and is arranged for a gauge of 4 feet $8\frac{1}{2}$ inches. The general arrangement of the truck frame, including side bar *a*, top plate *b*, body spiral springs *c*, and spring-post stay *d*, is similar to that in Fig. 6. The semielliptic body springs *e*, Fig. 7, are of special shape, with both limbs of each spring extending in the same direction toward the end of the top plate *b* of the truck; the outer end *f* of either spring is always in action, but the inner end *g* only comes into action as the truck is loaded, to prevent longitudinal oscillation of the car. The axle-box springs are elliptic instead of spiral and are duplicated; the top springs *h* carry light loads and are always in action, while the lower springs *i* only come into action on heavy load. The truck side bar *a* hangs from the top axle-box springs *h* by means of the suspension links *j*, while the lower axle-box springs press on spring caps *k*, directly under the side bar of the truck.

10. **Double Trucks.**—**Double trucks,** sometimes termed also **bogie trucks,** are usually arranged to turn about a certain fixed point, common both to the car and the truck, called the *pivotal*

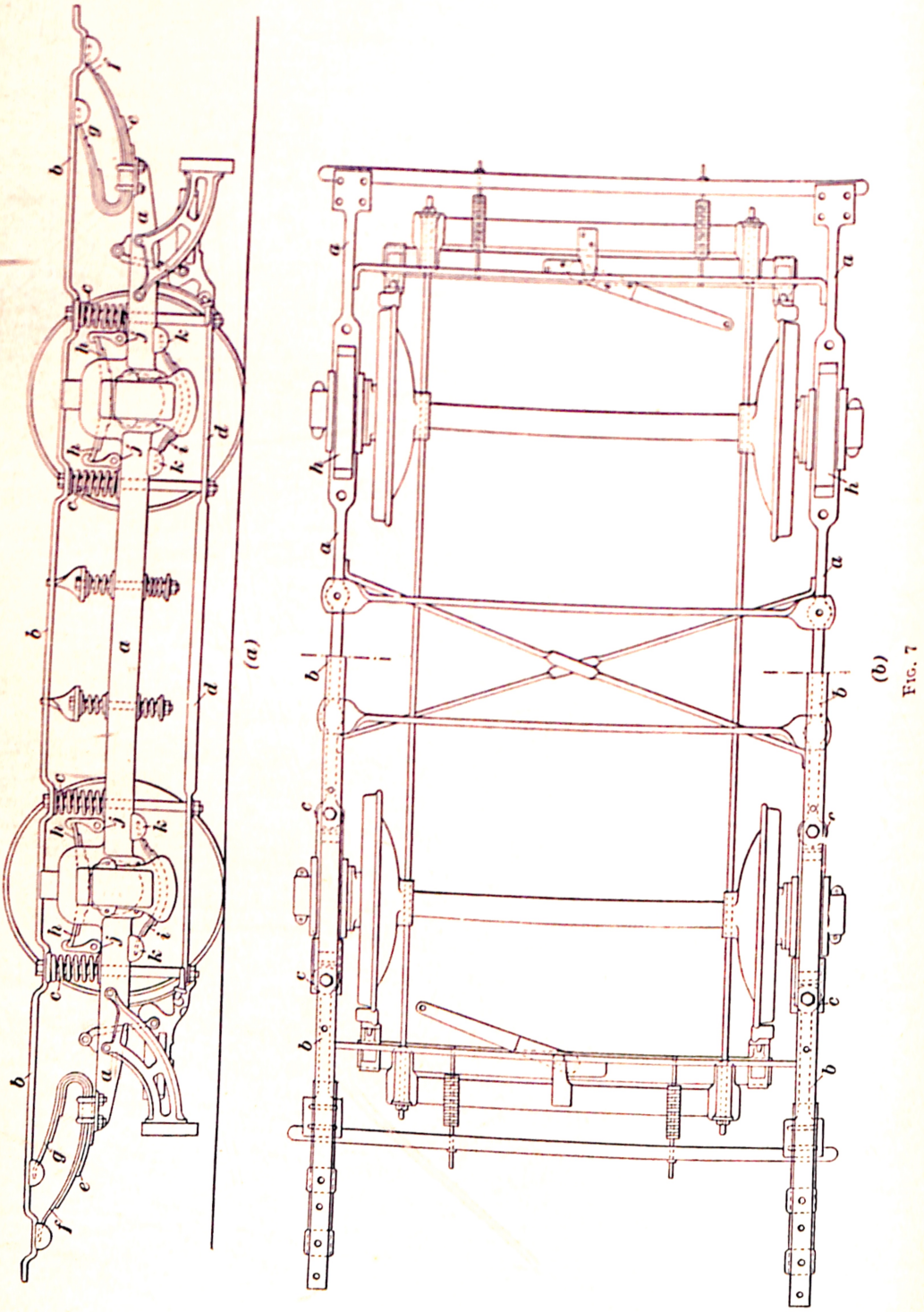


Fig. 7

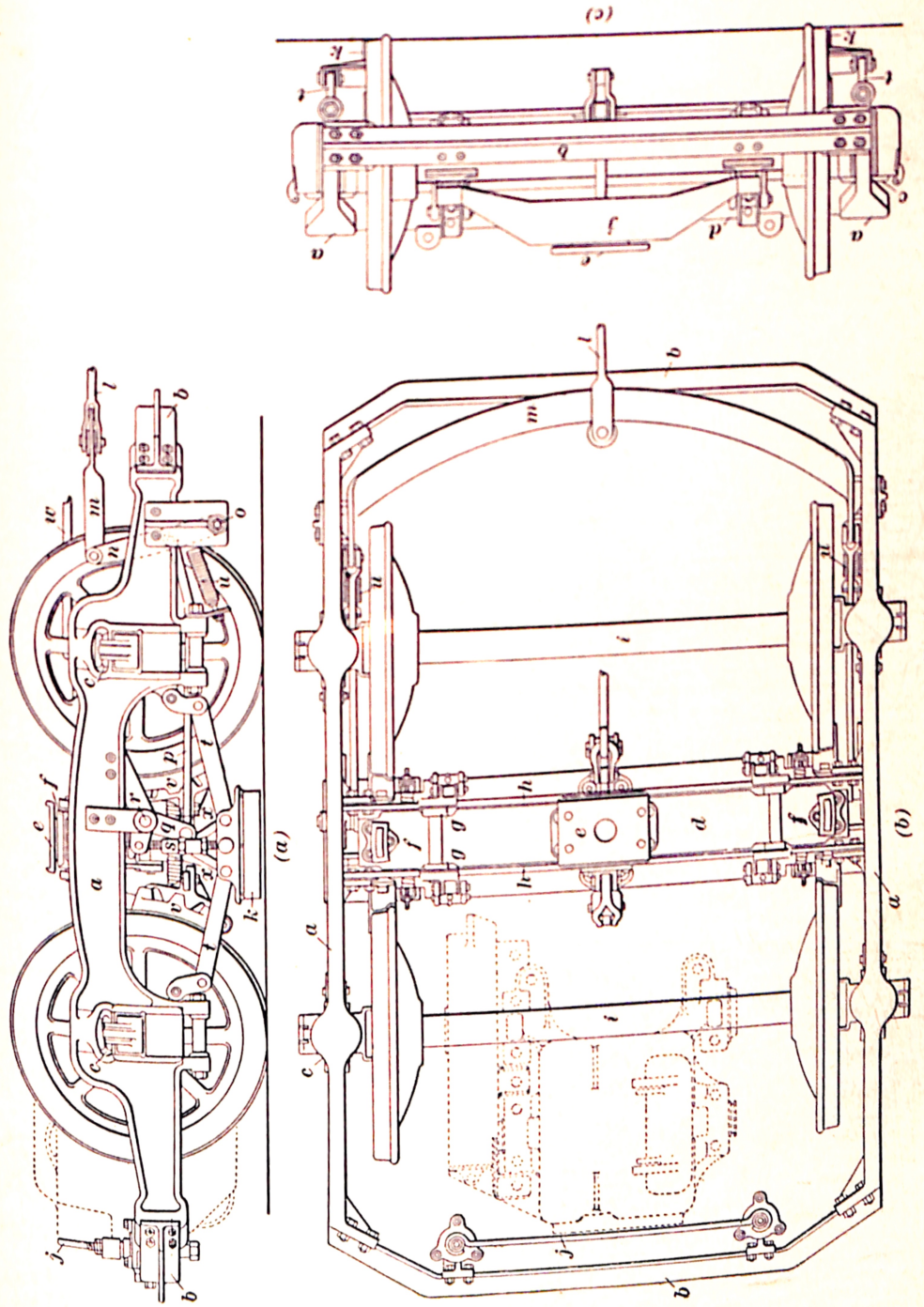


Fig. 8

point; the weight supported by the truck bears on a cross-beam known as the *bolster*. These trucks are therefore sometimes termed *swing-bolster trucks*, since the truck and bolster swing together about the pivotal point. All the wheels of a double truck may be of the same diameter, in which case the truck is known as an *equal-wheel truck*, and may be used with one or two motors. If only one motor is used per truck, the wheels on the driving axle may be of normal size, but the *pony*, or trailing, wheels on the second, or *pony, axle* may be much smaller, these wheels merely serving to guide the truck on the rails.

11. M.G. Equal-Wheel Truck.—A typical equal-wheel centre-bearing swing-bolster truck, known as the M.G. truck, is shown in Fig. 8, where (*a*) is the side elevation, (*b*) the plan, and (*c*) the end elevation. The wheel base is 4 feet 1 inch, the gauge is 4 feet $8\frac{1}{2}$ inches, and the wheels are $31\frac{3}{4}$ inches in diameter. The frame consists of cast-steel side bars *a*, which are connected by the end cross-bars, or *end sills*, *b*. Helical axle-box springs *c*, mounted on the top of the axle boxes and fitting into cups cast on the under side of the side bars, support the truck frame and the weight of the car body. The bolster *d* supports the car body on the swivel plate *e* and rubbing plates *f*; a centre pin on the car, known as the *king pin*, fits into the centre hole of the plate *e*. The ends of the bolster are spring-supported on helical springs which bear on a spring plank, which in turn is suspended by links *g* from transoms *h* which cross the truck from side bar to side bar. The side swing of the bolster is cushioned by spiral springs bearing against the side frames. The driving motor is hung between one car axle *i* and the spring support *j* carried on the end sill *b*; the outline of a motor is shown dotted in views (*a*) and (*b*). The truck is fitted with both track brakes and wheel brakes, which are operated independently of each other. The track-brake shoes *k* are applied to the head of the running rail when a pull is exerted on the brake rod *l*. This pull is transmitted through the arch bar *m*, and thence on each side to the lever *n*, which is pivoted at the fixed point *o*, and then through the tension rod *p* to the crank lever *q*, which is pivoted at *r*. When the lever *q* is turned in a counter-clockwise direction, the push

rod *s* depresses the brake shoe *k*. The brake-shoe holders are hung from the truck side frames by the links *t*, and the shoes are normally held clear of the rail by springs *u* pulling on the levers *n*. The wheel brakes *v* are operated by the brake rod *w* through levers not shown in the drawing. The wheel brakes are kept away from the wheel tires when not in use by means of the springs *x*.

12. Maximum-Traction Trucks.—If only one motor per truck is used, a greater tractive effort can be obtained by arranging for the driving wheels of a double truck to carry a larger proportion of the weight of the car than the trailing wheels. In the **maximum-traction truck**, or **proportional-traction truck**, matters are so arranged that the large driving wheels carry about 70 per cent. of the total weight on the truck, leaving 30 per cent. of the weight only to be carried by the small pony wheels. Using one motor per truck, therefore, on a route with moderate gradients, the maximum-traction truck is better, as regards freedom from skidding of the wheels, than the equal-wheel truck. When heavy gradients are to be climbed, the equal-wheel truck with two motors per truck is evidently the better practice. On level roads, and carrying only moderate loads, the pony wheels of the maximum-traction truck are liable to jump the rails at points or curves, so that, since there is not much liability for the wheels to skid, the equal-wheel truck is preferable even though fitted with only one motor per truck.

13. Brill Maximum-Traction Truck.—A Brill maximum-traction truck, without swing bolster, is shown in Fig. 9. The axles of the driving wheels *a* and pony wheels *b* are kept rigidly parallel, the respective axle boxes *c*, *d* being arranged to slide vertically in guides formed by the side bars *e* of the truck frame. The greater portion of the weight of the car is borne on the side cushions *f*, which are attached to spring posts *g*, and rest on the helical springs *h*. The remainder of the car weight rests on the adjustable spring pillar *i* and is made just sufficient to keep the pony wheels *b* on the track when rounding curves. This truck has no fixed pivotal centre, the point about which it swivels being determined by the four points of contact with the car body,

namely, the two side cushions *f*, the spring pillar *i*, and a king pin attached to the car body and working in a quadrant fixed to the front stay *j* of the truck frame, but not shown in the illustration. Side play of the car body is taken on the rollers *k*, which are recessed in the side cushions *f*, and which bear against rubbing plates on the car underframe. The absence of a central bolster enables the motor to be hung between the axles of the truck. The helical springs *l* cushion both up and down movements of the motor support *m*, while the axle-box springs *n*, *o*, which support the whole weight of the car and truck on the axles, are also of helical form. The brakes *p* are applied to the wheels by a pull rod moving the arch bar *q*, the motion of which

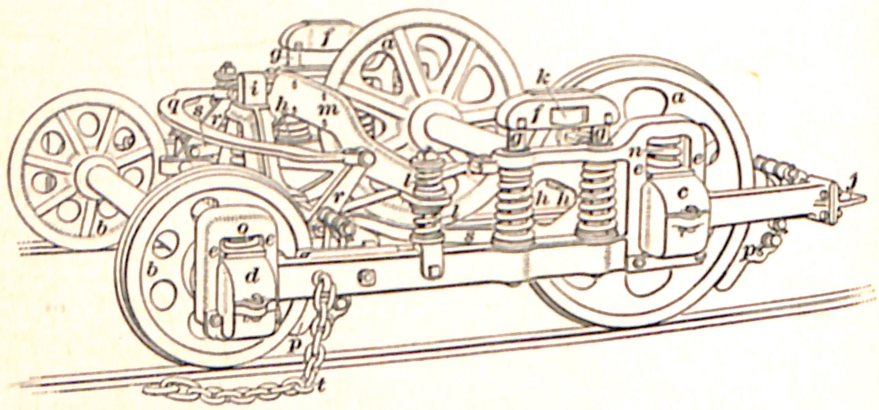


FIG. 9

is transmitted to the blocks through levers *r*, *s*. As the truck swivels in rounding curves, the pony wheels swing under the car ; a check-chain *t* is usually attached to the side bar of the truck and to a fixed point on the car underframe to prevent the truck swinging round too far if the pony wheels should jump the rails, or under any other abnormal circumstances.

14. London County Council Maximum-Traction Truck. — In Fig. 10 is shown a centre-bearing swing-bolster maximum-traction truck, which is specially fitted with a plough carrier, for use on the conduit system of the London County Council Tramways. The side elevation, plan, and half-sectional elevation are shown, respectively, in views (*a*), (*b*), and (*c*). The bolster *a*

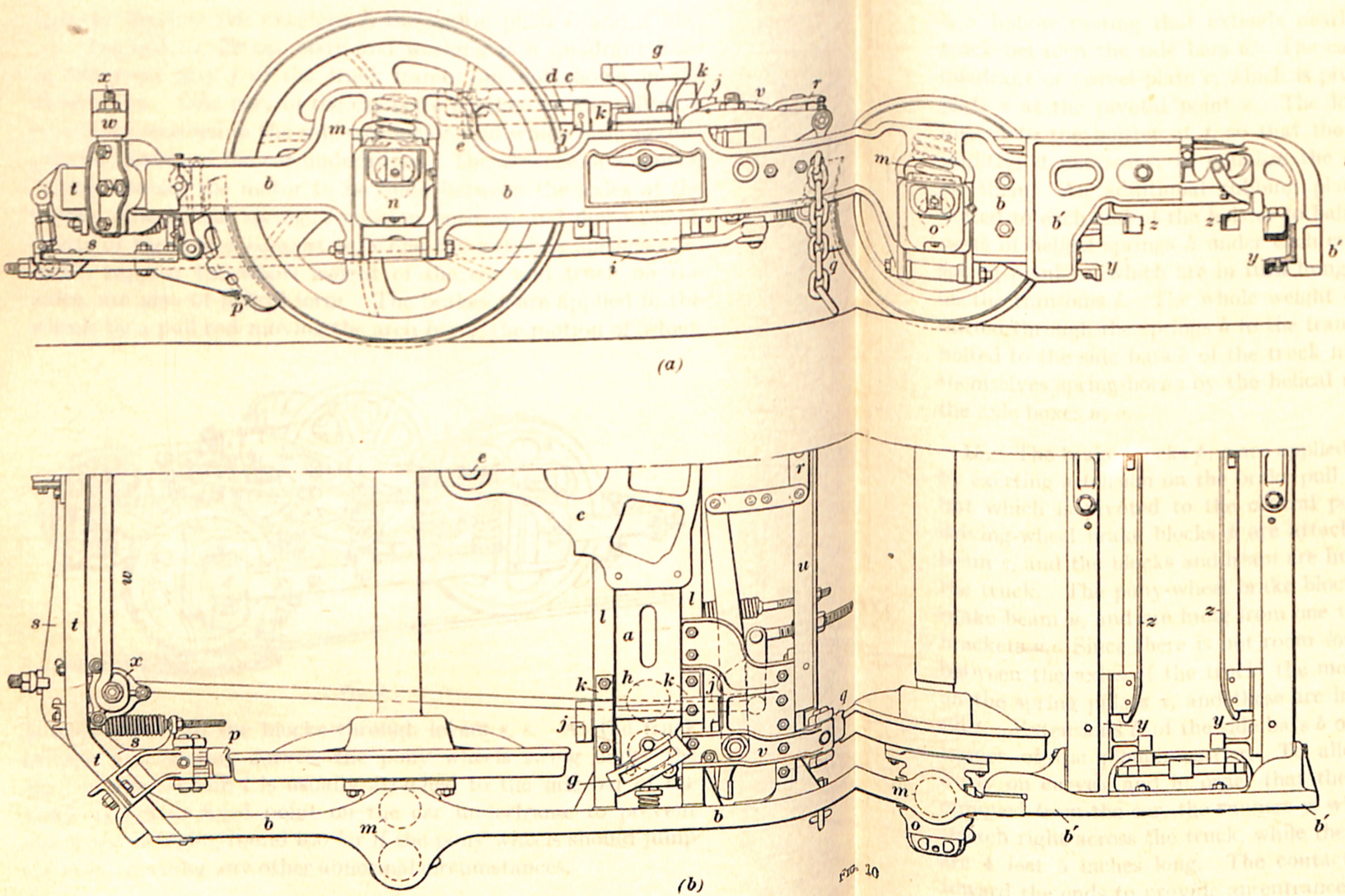
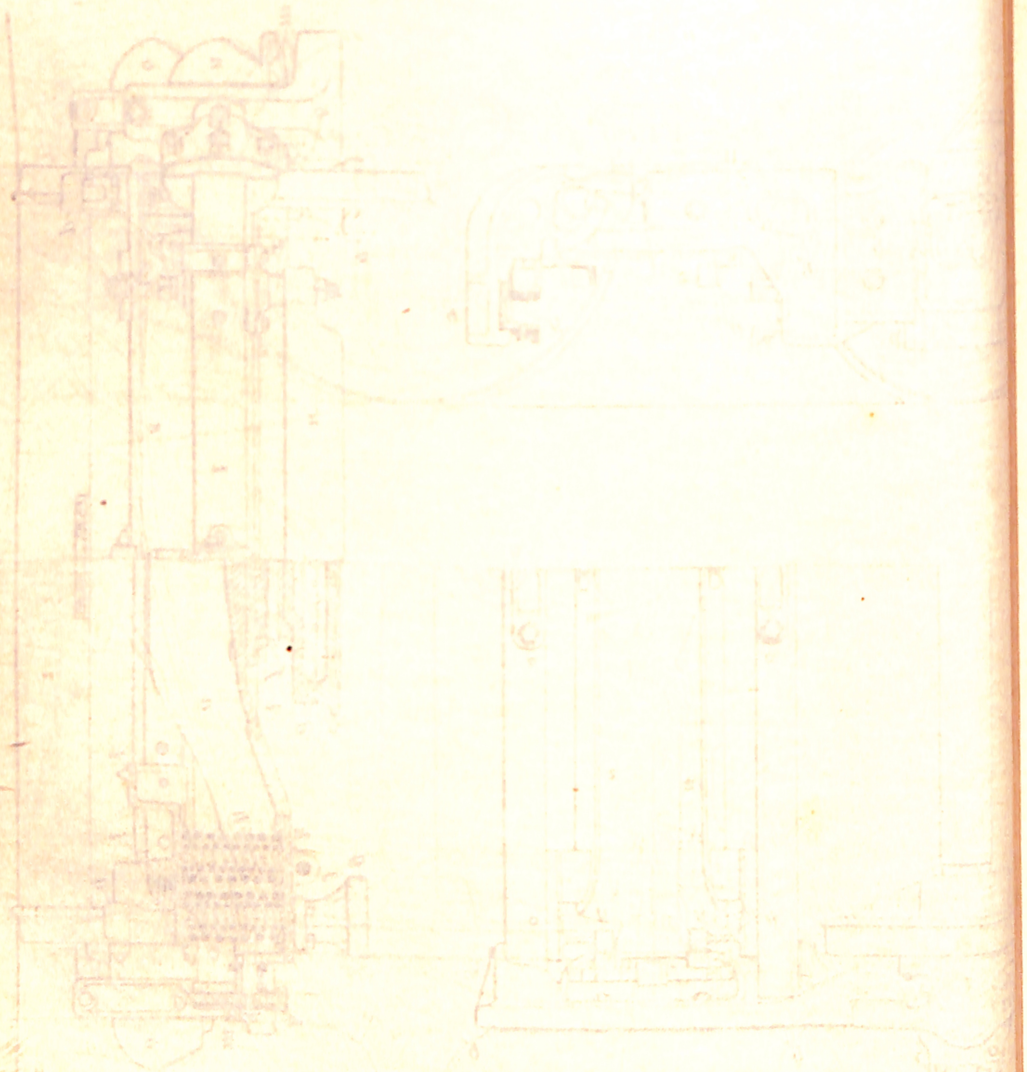


FIG. 10



is a hollow casting that extends nearly the full width of the truck between the side bars *b*. The car body rests on the top quadrant or swivel plate *c*, which is pivoted to the lower swivel plate *d* at the pivotal point *e*. The lower plate *d*, in turn, is hinged to the bolster at *f*, so that the swivel plates may rock slightly, if necessary, to equalize the distribution of the load on them. An additional rubbing plate or side cushion *g* is bolted to each end of the bolster to balance the car body. The nests of helical springs *h* under each end of the bolster rest on spring planks *i*, which are in turn hung by links *j* to brackets *k* on the transoms *l*. The whole weight of the car is thus transmitted through the springs *h* to the transoms *l*, which are rigidly bolted to the side bars *b* of the truck frame. The side bars are themselves spring-borne by the helical springs *m* on the top of the axle boxes *n*, *o*.

15. The brake blocks *p*, *q* are applied to the respective wheels by exerting a tension on the brake pull rod, which is not shown, but which is pivoted to the central point of the link *r*. The driving-wheel brake blocks *p* are attached to the curved brake beam *s*, and the blocks and beam are hung from the end sill *t* of the truck. The pony-wheel brake blocks *q* are attached to the brake beam *u*, and are hung from one transom by means of the brackets *v*. Since there is not room for the motor to be hung between the axles of the truck, the motor support *w* is carried on the spring pillars *x*, and these are in turn bolted to the end sill *t*. Extensions *b'* of the side bars *b* of the truck form the side frames of the plough carrier. To allow the truck to swivel freely on curves, and in order that the plough may readily be removed from the car, the runners *y*, which support the plough, stretch right across the truck, while the electrical contact bars *z* are 4 feet 5 inches long. The contact bars are curved away toward the ends to provide an entrance for the collector springs with which the plough is fitted. In many cases collector springs are not used, and connection is made to the plough by means of flexible insulated cables.

16. **Truck Bearings.**—A typical axle box and truck bearing of a Brill single truck are shown in Fig. 11. The axle-box casting *a*

has a seat at *b* for the axle-box truck springs, which are helical in form. The top bearing brass *c* carries the weight on the journal *d*, the car axle being shown broken at *e*, where the wheel would be shrunk on. The check-plate *f* is dropped into a groove *g* turned at the end of the axle, and limits the end play of the journal in the bearings. The oiler block *h* supports a felt pad, not shown, which conveys oil to the journal from the oil reservoir *i*. The oil-throwing ring *j* prevents oil travelling along the shaft from the axle box, the fibre washer *k* preventing the oil passing on to the oil thrower when the axle is at rest. The axle-box cover *l* is provided to allow inspection and to permit the removal of the check-plate *f* when it is desired to slide the axle-box off the journal.

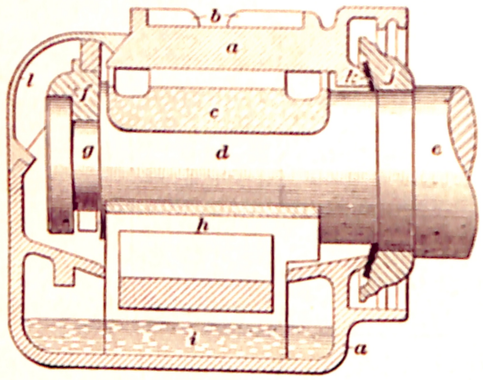


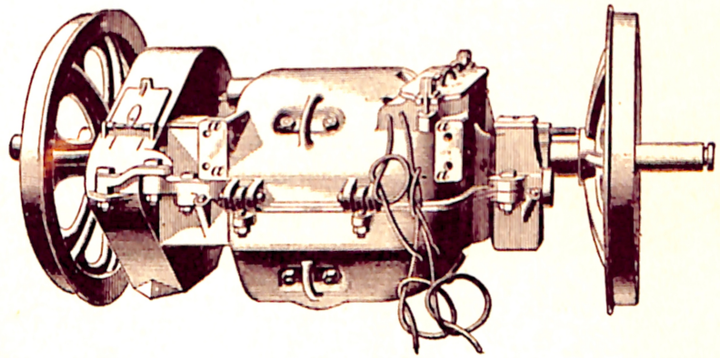
FIG. 11

METHODS OF SUSPENDING MOTORS ON TRUCKS

17. Position of Motor.—It is usual in tramway work to gear the motors to the car axles by means of a single-reduction gear; that is, a pinion at one end of the armature shaft drives a spur wheel on the car axle. The weight of the motor is then carried partly on the car axle and partly on the framing of the car truck. It is not possible in tramway work to mount the motor armature direct on the car axles; in order to suit the low axle speeds, the motors would have to be much larger and much heavier than is necessary when the motors are geared. Moreover, in order to minimize vibration of the car and wear of the track, it is undesirable to carry a greater weight than necessary directly on the wheels without the support of intermediate springs. When the motors are geared, the weight is partly spring-borne, but in the case of the direct drive the whole weight of the motors must usually be carried direct on the axles, in order to maintain the

correct centring of the armature and field. Direct driving is used in the case of some electric-railway locomotives, of which the axle speeds are also suitable as armature speeds of the large sizes of motors used. In these cases, arrangements are sometimes made also to carry the weight of the motors on springs, which would be too expensive to use in the case of tramcars.

18. Nose Suspension.—There are two principal methods of suspending a traction motor from the car truck, known, respectively, as the **nose suspension** and the **cradle suspension.** In either case the motor is hung on the car axle between the car wheels, as shown in Fig. 12, in which the motor occupies a central position between the car wheels: a gear-case, enclosing the spur


FIG. 12

gear, is shown at the left of the motor. The car axle passes through axle bearings at the rear of, and forming a part of, the motor case. In the nose suspension, the front is supported by a suspension bar bolted to the motor at *a* and resting on springs carried by the side frames of the truck.

In Fig. 13 (*a*) and (*b*) are shown the plan and front elevation of a completed nose suspension. The axle *a* passes through the axle bearings *b*. As this motor does not take up all the space between the wheel hubs, it is prevented from shifting along the axle on the one hand by the spur wheel *g* and on the other by the collar *c*, the position of which can be adjusted by a screw *d*. When the space between the wheel hubs is completely filled, no collar is necessary. When a collar must be used, instead of a split collar *c*,

with a screw adjustment, it is better practice to use a plain solid collar pressed on to the shaft in the same way as the wheels ; it is cheaper than the collar shown and there is no possibility of its working loose. The suspension bar to which the motor is bolted may be straight, as shown at e', or bent, as at e, but in either case it is supported by springs f carried on the frame of the truck

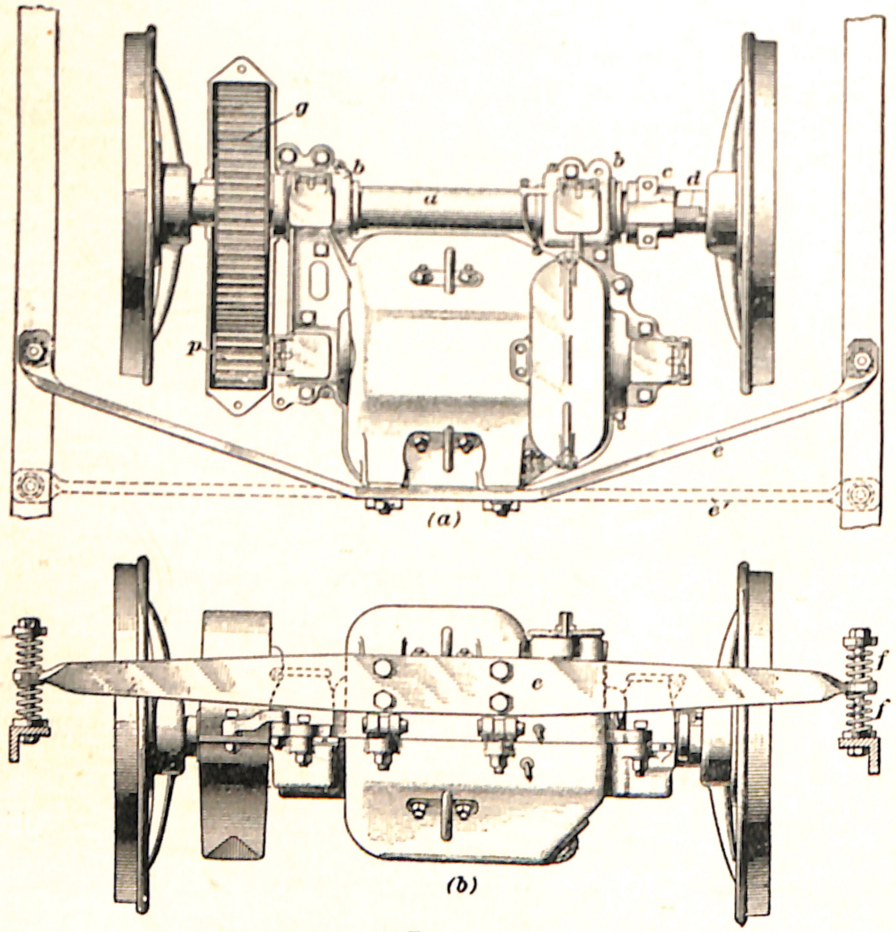


FIG. 13

Whatever kind of suspension is used, the object is to provide a flexible support for at least a part of the weight of the motor, so as to cushion the pounding effect and allow a certain freedom for up-and-down movement as the car passes over irregularities in the track. The stresses on both motors and track are in this way very much reduced.

19. Westinghouse Nose Suspension.—The nose suspension of the Westinghouse 200 tramway motor, shown in Fig. 14, is a very compact arrangement. The motor develops a normal output of 35 horsepower on a 1-hour rating, and is so arranged that it can be placed between the car wheels when spaced for a minimum gauge of 3 feet 6 inches. An end view of the motor and suspension from the gear-box end is shown in view (*a*) ; a side elevation, looking at the car axle, in view (*b*) ; and the general arrangement in plan in view (*c*). The axial width of the motor *a*, armature bearings *b*, and gear-box *c* is cut down to a minimum. Instead of bolting the motor frame direct to the suspension bar *d*, a lug *e* on the motor is hung from the suspension bar by a link *f*. In view (*a*) the dotted lines show the positions of the lower half *g* of the gear-case and the lower half *h* of the motor frame, when swung down in order to inspect the gear-wheels, or the motor armature or field coils, as the case may be. The cases are held closed by means of bolts and are made to fit closely, so as to exclude water and dirt.

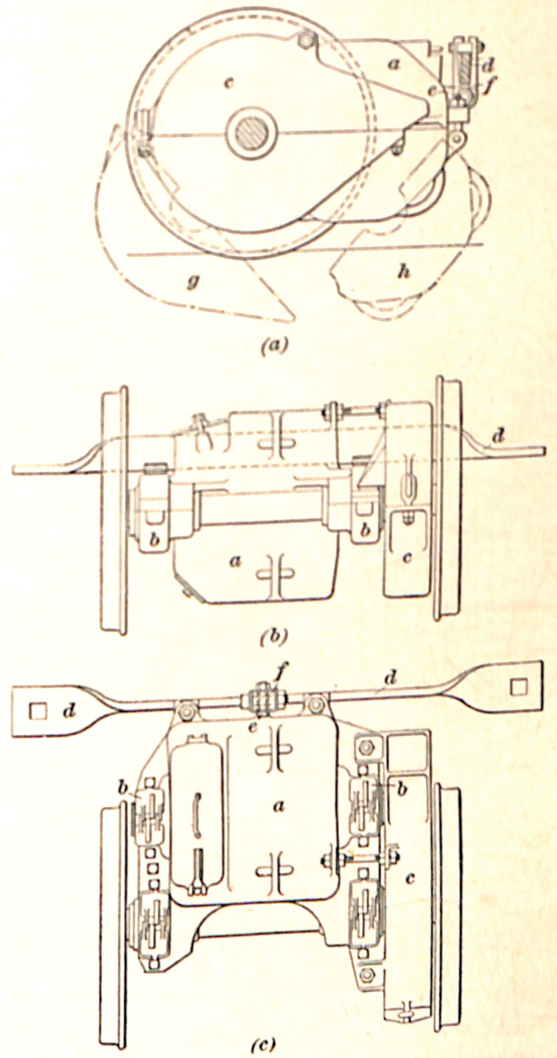
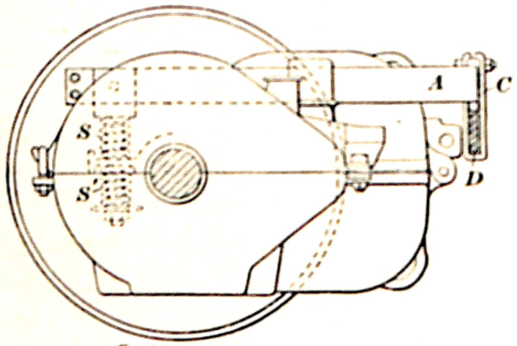
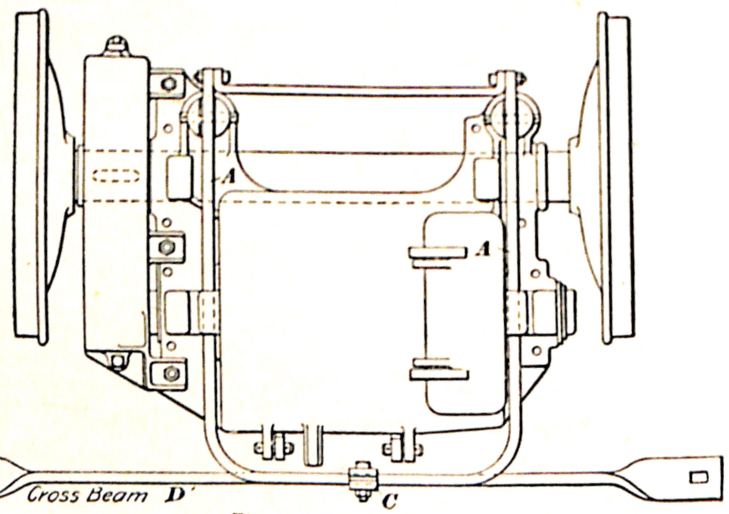


FIG. 14

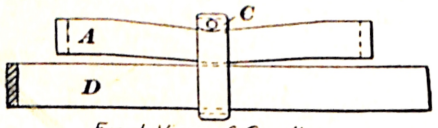
20. Double-Geared Drive.—Since the drive by a single-reduction gear through a single pair of gear-wheels is found to cause unequal wear of the bearings, thus allowing the pinion and spur wheel to lose their alinement and the teeth to wear more



End View
Cradle Suspension



Plan of Cradle Suspension



Front View of Cradle

FIG. 15

at one end than the other, it has been suggested that a much better drive can be obtained by using pinions on both ends of the motor shaft, driving on to two spur wheels, one at each end of the axle. Experiments show that, if sufficient room can be

found between the wheels for the extra gear, the results obtained are very satisfactory, both because the running is improved and the expense of upkeep of wheels and bearings is diminished.

21. Cradle or Side-Bar Suspension.—In Fig. 15 is shown a method of suspension sometimes used, in which the motor is supported by a cradle, or frame, *A*. The front of the cradle is supported by a link *C* from the cross-beam *D* that rests on the truck side frames, and in this example the back is supported by means of springs *S*, *S'* that bear against lugs cast on the same arm that carries the axle bearings. The sides of the cradle pass through lugs on the ends of the motor and the whole motor is free to move up and down through a limited range, the movements being cushioned by springs *S*, *S'* and those placed between the ends of the cross-beam and the truck side frame. In some forms of this suspension the side bars are below the centre line of the motor, in which case the ends must be hung from the cross-beam and the axle, respectively, by vertical links. In either case the object is to support the motor at a point as near as possible to its centre of gravity, and thus carry as much as possible of the weight of the motor on the springs.

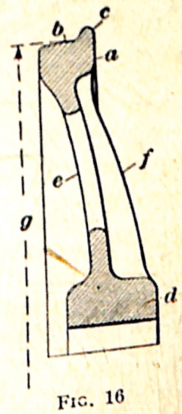


FIG. 16

CAR WHEELS

22. Form and Parts of Wheels.—The various parts of a car wheel are the *rim*, *tread*, *flange*, *boss*, *web*, and *ribs*. The principal wearing portion of the rim *a*, Fig. 16, and that part on which the wheel rolls, is the tread *b*. The flange *c* runs in the rail groove and serves to keep the wheels on the rails. The centre portion *d* of the wheel is known as the boss, while the web *e*, which is usually perforated, supports the wheel rim from the centre, and is itself stiffened with ribs or brackets *f*. The profile of a standard wheel, running on a standard tramway rail, is shown in Fig. 17. The gauge line of the rail is not the same as the gauge line of the wheel, but is slightly displaced, to allow clearance when the wheels are

rolling. For instance, if the track gauge is 4 feet $8\frac{1}{2}$ inches, the wheel gauge will be 4 feet $8\frac{5}{16}$ inches.

23. Size and Material of Wheels.—The diameter of a wheel is always understood to mean the greatest diameter *g*, Fig. 16, of the tread; for tramway work, this dimension may vary from 20 to 33 inches. The smaller wheels are used as the pony wheels of maximum-traction trucks; the most usual sizes of driving wheels are 30 and $31\frac{3}{4}$ inches in diameter. In Fig. 18 are shown two wheels *a* mounted on a car axle *b*, the track gauge being shown by the dimension *c*. The wheels are bored and the axle turned to a press fit, and the wheels are pressed on hydraulically. The journals *d* are of smaller diameter than the remainder of the axle, and run in the truck-axle bearings. The spur wheel of the

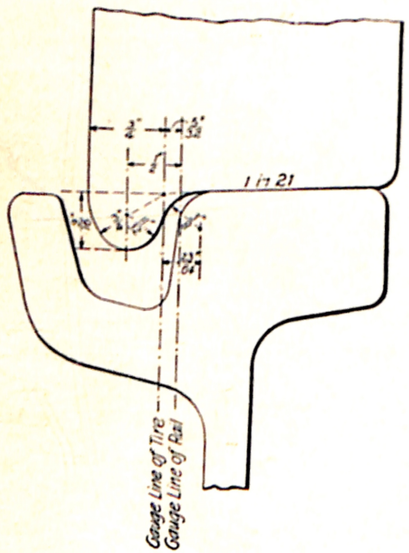


FIG. 17

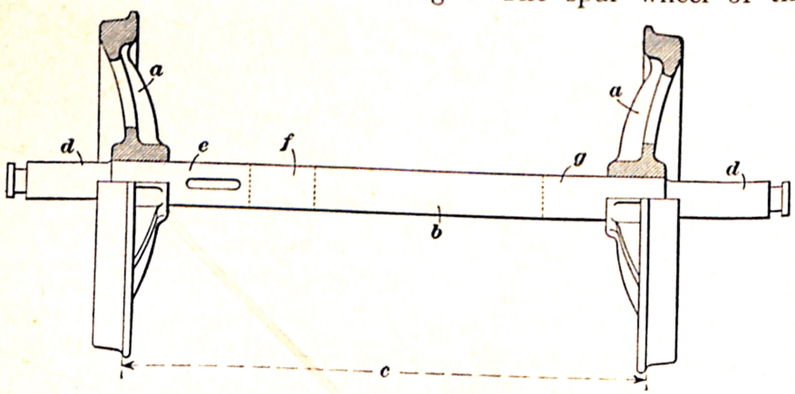


FIG. 18

single-reduction gear is clamped and keyed to the axle at *e*, and the motor-axle bearings hang on the axle at *f*, *g*. The

remainder of the axle, between *f* and *g*, need not be machined to a finish. Car wheels are made either entirely of chilled cast iron or are fitted with steel tires shrunk on centres of annealed cast iron, wrought iron, or pressed steel.

24. Chilled Cast-Iron Wheels.—**Chilled cast-iron car wheels** possess considerable elasticity and resistance to wear under tramway conditions. They are made from a specially good brand of pig iron, the treads and flanges being *chilled*, or made intensely hard by casting in a mould with metal faces at the tread and flange. The rapid cooling of the casting by the metal faces gives the desired local hardening, while the other faces and interior of the casting remain soft cast iron. The depth of the effective chilling, or hardening, is usually limited to about $\frac{3}{4}$ inch, so that when the wheel wears to this depth it must be scrapped. Within this limit, however, the wearing properties of chilled wheels are excellent. There are certain disadvantages in the use of these wheels, for there is a tendency for the wheel flanges to chip and break, and this tendency is the greater the harder the wheel. Also, since it is impracticable to turn up chilled wheels in the lathe, special means must be provided for grinding the wheels in order to prevent the development of flat places on the tread. These flat places, called *flats*, are made on the wheel treads when too great pressure is applied between the brake blocks and wheels in braking, thus locking the wheels so that they skid, or slide, along the rails instead of rolling. They are usually caused by careless driving, and much may be done to minimize trouble from this cause by the care of the driver in gradually applying the brakes. Since a braked wheel always tends to stop at the point where a flat has already commenced to form, the wheel should be ground true, by means of an emery grinder, before a bad flat is developed.

25. Steel-Tired Wheels.—**Steel-tired wheels** are much more expensive in first cost than cast wheels, but in some cases their use is more economical in the long run. They are not liable to breakage, and not nearly so likely to develop flats, and when flats do occur they can be removed in the lathe. Steel tires also have a higher coefficient of friction than cast wheels, and

therefore the adhesion of the wheels on the rails is increased, and the brakes are more effective. The tires are usually heated and then shrunk on the centres, so that when a tire is worn out it can be removed and a new one can be shrunk on.

In Fig. 19 (*a*) and (*b*) are shown two Griffin steel-tired wheels, the centres being of specially toughened and annealed cast iron.

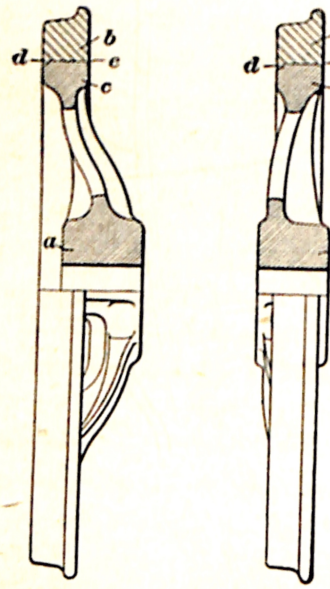


FIG. 19

View (*a*) shows a standard wheel for a gauge of 4 feet 8½ inches; this wheel is *dished*, that is, the centre line of the boss *a* is set back from the centre line of the rim, in order to give the wheel greater elasticity. The wheel in view (*b*) is of the *reversed-dish* type, the boss *a* being brought forwards in order to allow the maximum amount of room between the wheels; the reverse-dish wheel is designed specially for use on narrow gauges.

26. Construction of Tired Wheels. Annealed cast iron is, in general, superior to wrought iron for wheel centres. Since the permissible working stress under compression is greater for cast iron than for wrought iron, it is possible to allow greater shrinkage in putting on the steel tires than would be advisable with wrought-iron centres. Thus, the use of setscrews to prevent the tire coming off, the holes for which weaken both the tire and the centre, is obviated. In Fig. 19 (*a*) and (*b*) the joint between the tires *b* and wheel centres *c* is specially designed for the maximum security. A lip *d* turned on the tire fits in a corresponding recess in the wheel centre. The other side of the centre is turned off to a round corner *e*; after the tire is shrunk on, a projecting rim left

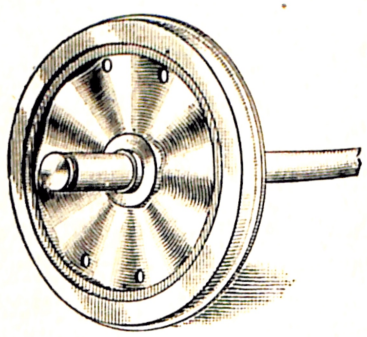


FIG. 20

on the tire is pressed down over the round corner, thus assisting to prevent any movement of the tire.

27. In Fig. 20 is shown one of the truck wheels on its axle, made by the Glasgow Railway Engineering Company, the centres being made in one piece in a hydraulic forging press, with steel tires shrunk on. The life of car wheels is measured by the mileage run before the wheels have to be replaced or re-tired. Chilled wheels have an average life under ordinary circumstances of 30,000 miles, while steel-tired wheels may run a distance of 50,000 or even 100,000 miles before requiring renewal.

LIFE GUARDS

28. Hudson & Bowring Life Guard.—The regulations of the Board of Trade provide that every tramcar shall be fitted with an approved pattern of life guard, designed to pick up without serious injury any person falling in front of a moving car. The arrangement of the Hudson & Bowring life guard is shown in Fig. 21; this is known as the *trigger* type. It does not depend

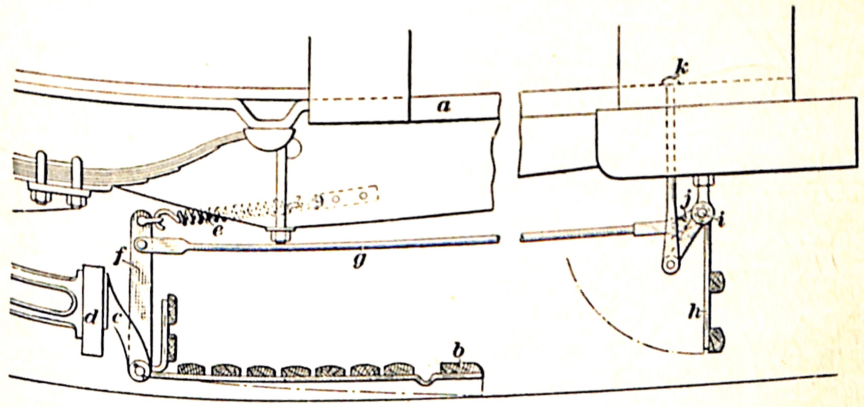


FIG. 21

for its operation on any action of the driver, but is entirely automatic. The life guard is fixed under the platform *a* of the car, and has a falling tray *b* carried normally a few inches above the rail level and pivoted to a bracket *c* fixed to the pilot board *d* of the car truck. The helical spring *e* is fixed at one end to the car-body underframe and pulls on the lever *f*, which is fixed

rigidly to the life-guard tray *b*; the spring thus tends to lower the falling tray and to hold its front end down to the surface of the road. Any movement of the lever *f* is prevented, however, before the life guard is required to act by the push rod *g*. If the car approaches a person lying on the track, the swinging gate *h*, which is pivoted at a fixed point *i*, is pushed back, and the crank-lever *j* is rotated on the pivot *i* until it is above the dead centre on the horizontal line, thus allowing the spring *e* to force the rod *g* forwards and to lower the tray *b*. The tray is reset by the driver depressing the platform pedal *k*; this rotates the lever *j* in a counter-clockwise direction, and rod *g* is put into compression, thus raising the tray *b*.

EQUIPMENT OF CARS

COLLECTORS

TROLLEY HEADS

29. The usual method by which current is collected by a moving car is by means of a wheel, called the **trolley wheel,** carried on the end of a **trolley arm** or **trolley boom,** so that it runs against the overhead trolley wire. The casting in which the wheel runs is known as the **trolley head**; it is either fixed rigidly to the trolley boom, for centre running, or is arranged to swivel on a vertical axis at the end of the trolley arm, for side and centre running, or side running only, according to the type of overhead construction with which it is used. Since the height of the trolley wire is usually not less than 20 feet above the ground, and may be more, the trolley arm is usually from 13 to 18 feet long. The necessary stiffness is obtained by making it in the form of a steel tube that tapers from 2 inches in diameter at the butt to 1 inch at the top.

30. Construction of Fixed Trolley Head.—The **fixed trolley head** is the earlier type and is still used with success on some

centre-running tramway systems in the British Isles, notably at Glasgow. In America the fixed head and the centre-running trolley are used practically to the exclusion of the swivelling head and side-running trolley. This head, as used in Glasgow, is shown in Fig. 22, in which the trolley head *a*, which is a gunmetal casting, carries the trolley wheel *b*, and is itself fixed to the trolley arm *c*. The trolley arm is insulated from the head and wheel by means of the insulating sleeve *d*, which is clamped on a contracted portion of the head by screwing the special nut *e* over the tapered and split sleeve *f*. If current were allowed to pass directly from the gunmetal wheel *b* to the steel spindle *g*, the grease used for lubrication would be dried, and the heat developed and the wear caused would be excessive. In this instance, therefore, springs *h* are provided, which are attached to the trolley head and collect current from the boss of the trolley

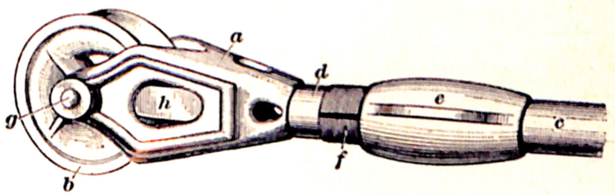


FIG. 22

wheel. It should be noted that the trolley head, as a whole, has no projections at any point which can catch in, and thus damage, the overhead construction in case of the trolley wheel leaving the wire. The material of the head-casting is sometimes malleable iron instead of gunmetal.

31. Swivelling Trolley Head.—A Birkby trolley head, which is a good example of the class of **swivelling trolley heads,** is shown in Fig. 23 (*a*) and (*b*). The brass head-casting *a* is fixed to the trolley arm *b*, and the brass or gunmetal trolley wheel *c* runs on a steel spindle *d* supported in the swivelling part *e*, called the *globe*. The lower portion of the globe is in the form of a spindle, which revolves in a socket in the head-casting, so that the trolley wheel can take up any desired position in the head in order to aline itself with the overhead trolley wire, and is prevented from jumping out by a pin *f* which engages in a groove

in the globe spindle. The shape of the head-casting and globe is designed so as to guard as much as possible against the head catching in the trolley or span wires if the wheel leaves the trolley wire.

32. Sliding Contact Sleeve.—In order to prevent breakage of the trolley or span wire, or damage to the trolley boom or the standard by which it is attached to the car, in the event of entanglement of the head with the trolley-wire construction, the Board of Trade regulations require means to be provided whereby the trolley head can be disengaged from the trolley arm when a pull is exerted on it under these conditions. This

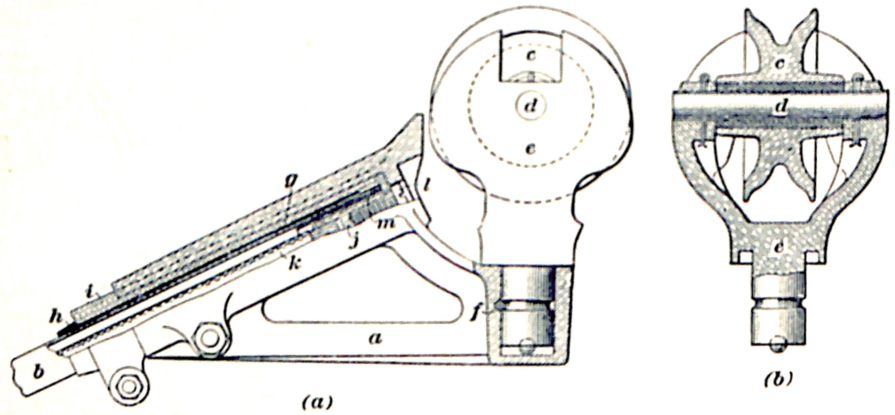


FIG. 23

is provided for in this case by the use of a split sliding contact sleeve *g*, Fig. 23 (*a*). The sleeve is clamped to the trolley boom *b* with a rubber insulating sleeve *h* interposed to insulate the boom, and then the head is slipped over sleeve *g* and clamped up lightly only. A projection *i* on the contact sleeve fits into a slot in the head-casting and prevents the latter turning, but the head is free to pull off in case of accident. The trolley cable connection is made inside the contact sleeve *g* by means of the cable terminal *j*, into which the bared end of the insulated cable *k* is sweated. The terminal is secured by the screw *l*, and is insulated from the steel arm *b* by means of an insulating fibre sleeve *m*. There are usually no collecting springs provided in swivelling trolley heads, for the trolley wheel is bushed with graphite, which is not only a good lubricant, but also a good electrical

conductor. The current passes directly from the trolley wheel to the spindle, and thence through the globe and head-casting to the trolley cable.

33. Self-Righting Trolley Head.—A modification of the swivelling head, used for centre-running systems, is the **self-righting trolley head**, shown in Fig. 24. The globe *a* carrying the wheel *b* is mounted in a socket in the head-casting *c*, and is free to swivel through a limited angle to follow any slight deviation or irregularities in the line of the trolley wire. The motion of the globe is constrained, however, by a spring *d* anchored at *e* to the head-casting, and pulling on a steel pin *f* passing through

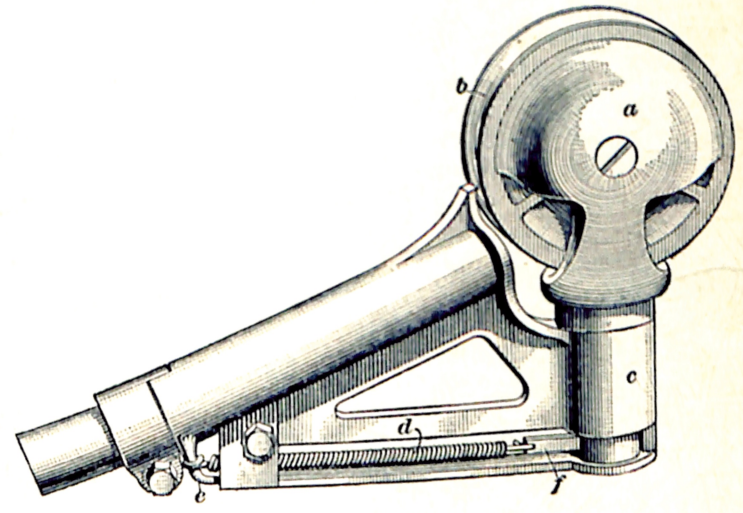


FIG. 24

the lower end of the globe spindle. The tendency of the spring is therefore to keep the axis of the trolley wheel always at right angles to the trolley arm, while the limited amount of flexibility allowed prevents undue strain of the overhead work and the trolley arm, and decreases the amount of wear of the trolley wheel.

TROLLEY WHEELS

34. Choice of Trolley Wheels.—Since the trolley wheel runs directly on the overhead trolley wire, great care must be exercised in choosing the most suitable wheel to use in any

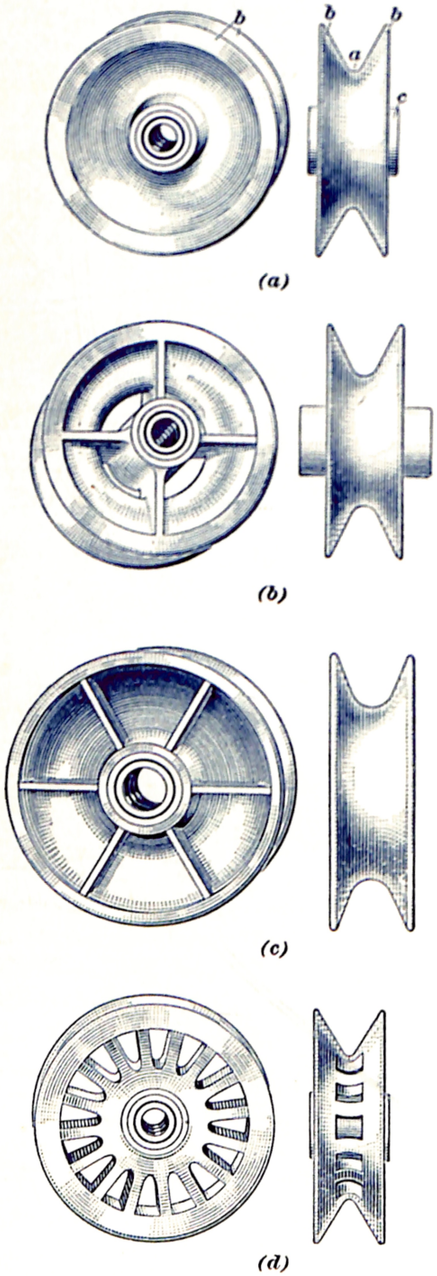


FIG. 25

given case to ensure both good collection of current and also a minimum of deterioration to the trolley wire. Trolley wheels are usually made of brass, gunmetal, or phosphor bronze, and the grade of metal must be chosen so that it is not so soft as to wear away quickly nor so hard as to cause undue wear of the trolley wire. The speed of the cars, the material and the disposition of the overhead wire with regard to the track, and the class and arrangement of the overhead fittings all affect the design of the trolley wheel.

35. Typical Trolley Wheels. — The diameter, width, and length of boss of the trolley wheel are settled in conjunction with the dimensions of the trolley head; the usual diameters vary from 3 to 5 inches, the most common sizes being $3\frac{3}{4}$ and $4\frac{1}{4}$ inches. The shape of the groove depends on the size and shape of the trolley wire and the design of the overhead ears. A trolley wheel with a special-shaped groove was shown in Fig. 23 (*b*), and wheels with

plain grooves are shown in Fig. 25 (*a*), (*b*), and (*c*). The wheel in Fig. 25 (*a*), of which *a* is the groove, *b* the flanges, and *c* the boss, is known as a *solid wheel*, being a gunmetal casting, simply turned up in the lathe to shape and afterwards bushed. A *spoke wheel* is shown in Fig. 25 (*b*), this wheel being somewhat lighter in weight than the former, but with a wider boss to suit a different pattern of head. A larger wheel, designed for running at high speeds, is shown in Fig. 25 (*c*); the groove is made wide, in order to give the trolley wire and ears sufficient clearance at curves, turnouts, etc. A *sleet-cutting wheel*, for clearing the trolley wire of sleet before cars fitted with the ordinary trolley wheel can run, is shown in Fig. 25 (*d*). The first car to run out over the line after a snowstorm would have a sleet-cutting wheel of this form; the perforations in the groove cut the sleet and allow it to fall out through the holes in the flanges.

36. Lubrication of Trolley Wheels.—Oil lubrication is never used for trolley wheels, because it is impossible to maintain a steady supply of oil to the bearing, and because any heating of the wheel or spindle due to the electric current will tend to dry up the oil. For fixed trolley heads, which allow the current to be collected from the wheel by a spring in the trolley head, *self-lubricating spindles*, for grease lubrication, have been used. An example of a self-lubricating spindle is shown in Fig. 26.

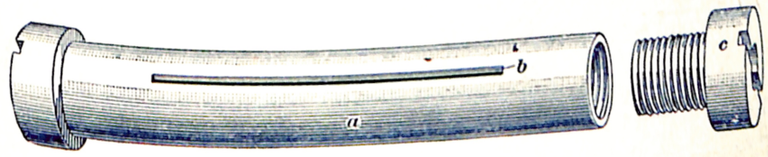


FIG. 26

The hollow spindle *a* is filled with vaseline, which reaches the bearing through the narrow slit *b* when the temperature rises sufficiently to melt it. The lubricant is retained by the screw cap *c*. For swivelling trolley heads, in which collecting springs, rubbing against the trolley wheel, cannot be used, neither grease nor oil lubrication is suitable, because of the heating effect of the current, and wheels utilizing solid lubricant must be used. The wheels shown in Fig. 25 are fitted with patent

oilless bushes. Grooves are machined on the inside and ends of each bush, and the grooves are packed with special solid lubricant, usually some form of graphite or graphite preparation. By this means wear is reduced to a minimum, and good electrical conductivity is maintained between the wheel and the spindle

37. Pressure of Wheel on Trolley Wire.—The pressure of the wheel against the trolley wire varies from 15 to 25 pounds, according to local conditions and the speed at which the car is to run. Too light a pressure will permit the wheel to jump off at the overhead fittings and at curves, while excessive pressure will wear all parts unnecessarily. Under ordinary conditions the pole should make an angle of about 45° with the car roof and the upward pressure on the wire should be about 20 pounds.

TROLLEY STANDARDS

38. Forms of Trolley Standard.—The device which holds the trolley arm and presses it upwards against the trolley wire is placed on the roof of a car and is known as the **trolley standard.** Its design depends on the type of car on which it is to be used. On double-deck cars without any top cover the trolley standard consists of a pedestal about 5 feet high, which must be insulated from the trolley wheel and connected to earth. On covered double-deck and single-deck cars the pedestal standard is not necessary, so a dwarf pattern is used ; the trolley standard for a covered car need not be insulated. Springs are arranged in the trolley standard, so that the wheel carried on the trolley arm is made to follow the trolley wire and to maintain the necessary upward pressure on it if the height of the wire changes due to the contour of the ground or due to the necessity of passing under bridges, etc.

39. Double-Deck Trolley Standard.—In the B.T.H. **double-deck,** or **pedestal, trolley standard,** shown in Fig. 27, the cast-iron base *a* is bolted to the top deck of the car, and supports a fixed outer tube *b*, at the upper end of which the revolving head *c* is carried on ball bearings *d*. Pivoted to the revolving head at *e*

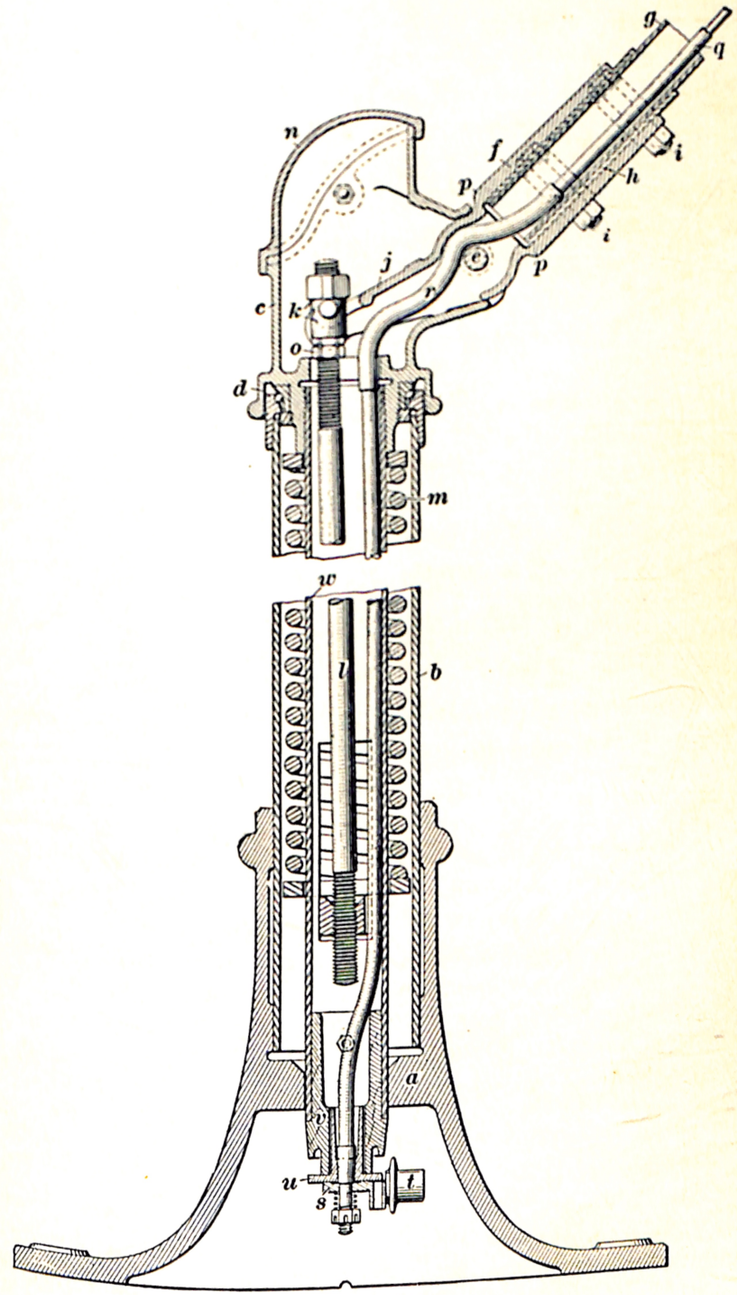


FIG. 27

is the working lever or pole socket *f*, into which the trolley arm *g* is clamped by means of the clamping plate *h* and bolts and nuts *i*. The lower end of the lever *f* is in the form of a hook *j*, which engages with the nut *k* and exerts a pull on the tension rod *l*, putting the spring *m* into compression when the trolley arm is depressed and maintaining an upward pressure of the trolley wheel. The compression of the spring *m* may be adjusted by removing the weather cap *n* and turning the nut *o* with a special key. Stops *p* prevent the trolley arm rising to an angle at which it might cause injury to the overhead work; they also prevent its being pulled below the horizontal. The trolley cable *q* passes down the trolley arm from the trolley head, and is specially protected by a rubber tube *r* where it passes into the standard from the trolley arm. Special provision is made, by means of a revolving contact at *u*, so that the trolley arm may be turned in either direction and to any extent. The porcelain insulator *t* carries a fixed contact *s*, and this engages with a revolving contact *u* which is attached to the wooden insulator *v* and is turned with the revolving head by the inner tube *w* of the pedestal.

40. Dwarf Trolley Standards.—The trolley standards used for single-deck cars are sometimes similar to the top-deck pedestal

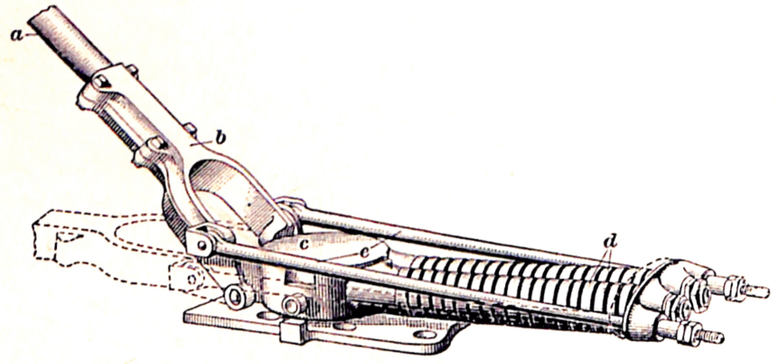


FIG. 28

standard, but much lower and often arranged with external springs. In this case it is not compulsory to insulate the standard from the trolley wire, and conditions of safety do not require the mechanical parts to be enclosed. Where double-deck top-covered cars are used and the clearance under railway bridges is very little, a special design of dwarf trolley standard is used. The B.M.R. standard, shown in Fig. 28, is so arranged that, when the trolley arm is horizontal, no part of the standard is more than 4 inches above the trolley board on the roof of the car. The trolley arm *a* is clamped into a forked lever *b*, which is pivoted at the lower extremities to the revolving head *c*. Two helical springs *d* are held in a frame on the opposite side of the head to the trolley arm; the compression of these springs, transmitted to the lever *b* through the tension rods *e*, causes the trolley arm and wheel to exert the necessary upward pressure against the trolley wire when running. The dotted lines show the positions of the parts when the trolley pole is depressed to a horizontal position when passing under bridges, etc.

AUXILIARY APPARATUS

CAR RESISTANCES

41. The **car resistance,** or **rheostat,** carried on every car for starting purposes and for rheostatic braking, is an important part of the car equipment, since the operation of the car is dependent on the use of the resistance for all changes in speed that are made by the car driver. The resistance is usually made up of cast-iron grids, but in some cases the units composing it are coils of iron ribbon. In either case, the resistance is assembled on a suitable frame, and either hung under the car floor or placed on the driver's platform. The former position has been the more widely adopted, but it has the disadvantage that mud and water are thrown on the resistance from the car wheels. In the case of double-deck cars, there is generally sufficient room for the resistance to be put under the stairway, in which case this position is to be preferred.

42. Grid Resistances.—One form of cast-iron resistance grid is shown in Fig. 29. View (*a*) shows the shape of a single cast grid *a* and the method of supporting it on three bolts, shown

in cross-section, which are threaded through the lugs cast on the grid for this purpose. The middle lug is used merely for support to prevent the grid sagging, but the end lugs serve also for making electrical connection to the grid by means of the screws shown. As shown in view (*b*), the grids *a* are threaded

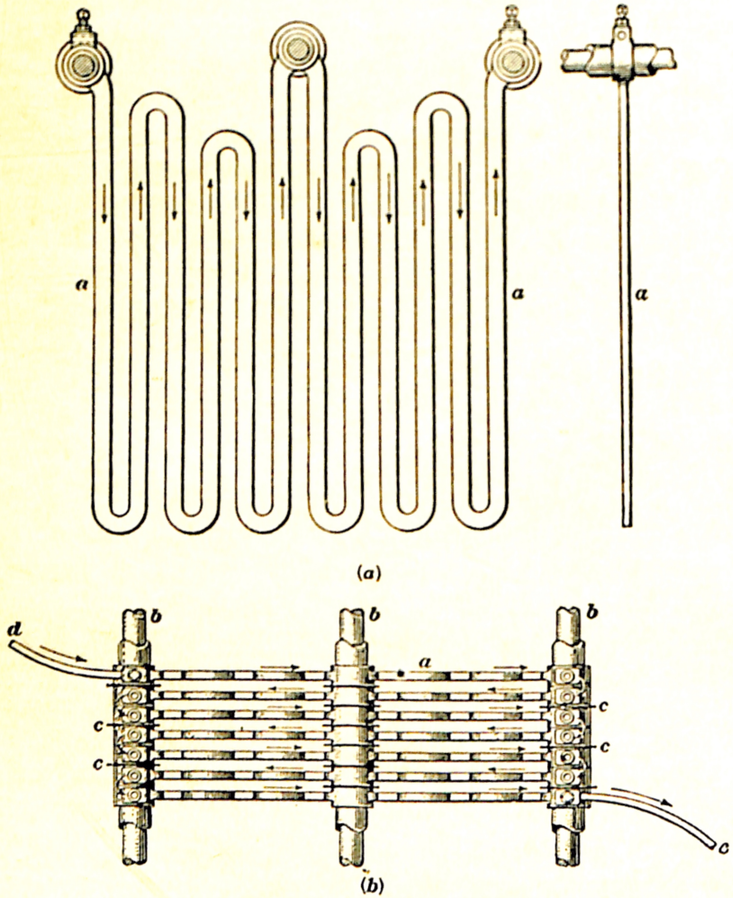


FIG. 29

on the insulated bolts *b*, and are insulated from each other by means of mica washers *c*. These washers *c* are so placed as to completely insulate the central lugs of adjacent grids, but successive pairs only of the end lugs are insulated, allowing electrical contact to be maintained between adjacent pairs when the whole

resistance is tightened up on the supporting bolts. The path of current through this section of resistance from the tapping lead *d* to the lead *e* is shown by the arrows, and is such that the current passes through every section of the resistance. The path of current through a single grid is shown by the arrows on the grid in view (*a*).

43. A later form of resistance grid, the B.T.H. type G T, is shown in Fig. 30. This form, shown in view (*a*), is adopted

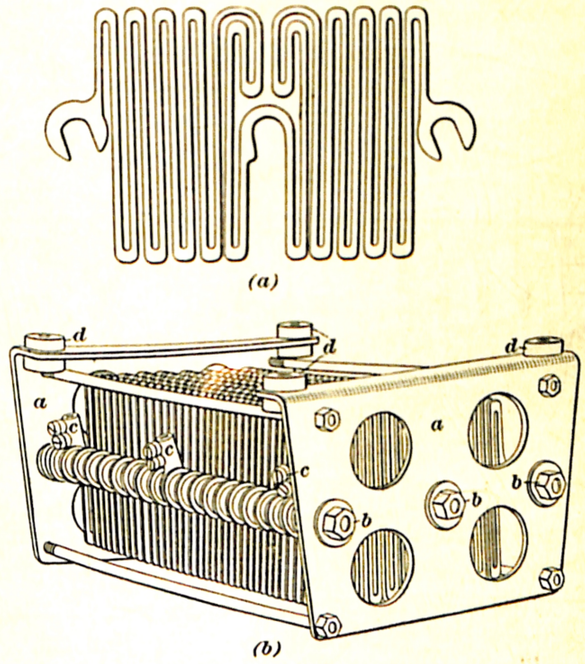


FIG. 30

in order to make the most effective use of the resistance material and, at the same time, to provide three supporting points on the centre line of the grid and thus obtain the maximum stiffness. The complete resistance, as assembled ready for mounting on the car, is shown in view (*b*). The end frames *a* are formed of steel plates, which are both stronger and lighter than cast iron, which is often used for the same purpose. Mica insulation is used throughout, mica tubes being used to insulate

the tie-bolts *b*, mica washers being placed between the resistance lugs. The brass terminals *c* provide means of making electrical connections to the resistance. The frame is suspended from the car floor by bolts which pass through holes *d*, bushed with fibre, in the feet of the end frames. Any section of the resistance may be withdrawn and replaced by simply slacking off the tie-bolts and slightly separating the grids at the desired points by sliding them along the bolts *b*.

44. Ribbon Resistance.—The Westinghouse circular pattern of car resistance is shown in Fig. 31. In this case each unit of the resistance consists of a spiral coil of iron band or ribbon, wound in the same manner as a clock spring and insulated with mica. Ventilation is provided for by leaving spaces between adjacent coils, when they are assembled between end plates on

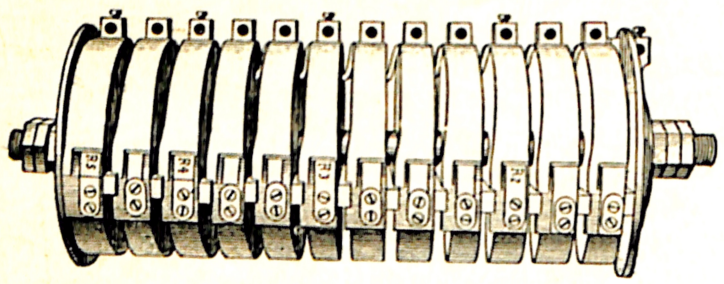


FIG. 31

a supporting bolt passing through the centres of all the coils. Terminals and binding screws are provided for making the necessary electrical connections, and the various points *R2*, *R3*, *R4*, *R5*, dividing the resistance into sections, are chosen to suit the particular controller used, and are marked with the respective letters and numbers for purposes of ready identification.

SWITCHES AND CIRCUIT-BREAKERS

45. Types of Switch.—The Board of Trade regulations require that an emergency switch shall be provided on every car and fixed so as to be conveniently reached by the driver in case of any failure of action of the controller. Since the driver operates the car from either end, according to the direction in which the

car is travelling, a switch is placed underneath the canopy over the platform at each end of the car. The driver thus has one switch always within reach. The two switches are connected in series in circuit with the trolley cable. One of the switches is arranged with a solenoid and automatic tripping device to open the circuit if the current rises to some predetermined excessive value; this is called the *automatic circuit-breaker*, or simply the *car breaker*. The plain switch at the other end of the car is termed a *canopy switch*. In some instances, fuses are connected in series with the two switches to open the circuit if the circuit-breaker should fail to act.

46. Westinghouse Canopy Switch.—The general appearance of the Westinghouse canopy switch is shown in Fig. 32. The switch is enclosed in a cast-iron case *a* provided with feet *b* for bolting the switch to the canopy of the car, and is protected by a cast-iron cover *c*, perforated at *d* to allow of the insertion of a screwdriver to tighten up the binding screws holding the cable connections. The handle of the switch *e* projects through an opening in the bottom of the case. The internal arrangement of the switch is shown in Fig. 33, in which view (*a*) shows a plan of the switch with the cover removed, and view (*b*) shows a cross-section through *A B*. The switch lever *a* is pivoted at *b* between two slate blocks *c*, *d*, which are separated by distance pieces *e*, *f* and distance tubes *g*. A wooden partition *h* is placed between the two arms of the switch lever, only one, *i*, of which is shown in view (*a*). Each arm carries a spring switch jaw *j*, which closes on the fixed switch blades *k*, *l* when the switch is in the on-position, as shown by the dotted lines in view (*a*). The line wires are brought into the top of the switch, through the wooden cover *m*, and are secured in the brass terminal blocks *n*, *o*, which are electrically connected to the switch blades *k*, *l*. Spring clips *p* are provided on each arm of the switch lever, which engage with the distance piece *f*

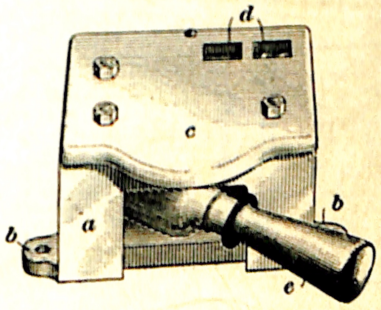


FIG. 32

when the switch is open, and keep the handle *q* in the off-position. The cover *r* normally protects the working parts, and the feet *s* are provided on the base for fixing the switch to its support.

47. Westinghouse Car Circuit-Breaker. — It is not usually necessary to provide magnetic blow-out coils in connection with canopy switches, though some makers employ them. For automatic circuit-breakers, however, magnetic blow-out devices are always fitted, and, if possible, the same coil that is already

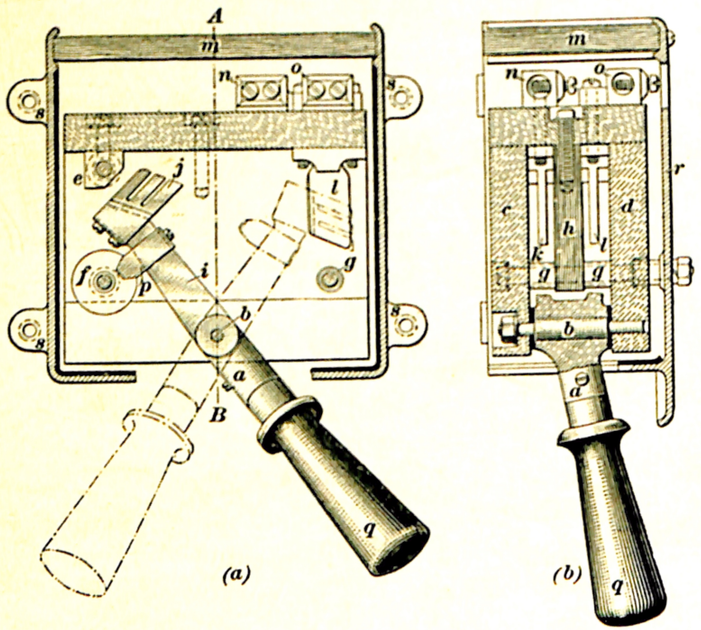


FIG. 33

provided to operate the tripping mechanism of the switch is utilized to produce the magnetic blow-out field. The Westinghouse automatic car circuit-breaker, which is shown in Fig. 34 (*a*) and (*b*), employs one solenoid coil for both purposes. The exterior of the circuit-breaker is shown in view (*a*). The working parts are enclosed in a cast-iron case *a*, provided with feet *b* for bolting to the support. A cast-iron cover *c* prevents access to live parts of the switch, but has an opening for the operating handle *d* and a flue *e* in which is extinguished any arc formed

between the contact points of the switch on breaking circuit. The small milled screw *f* is provided for adjusting the circuit-

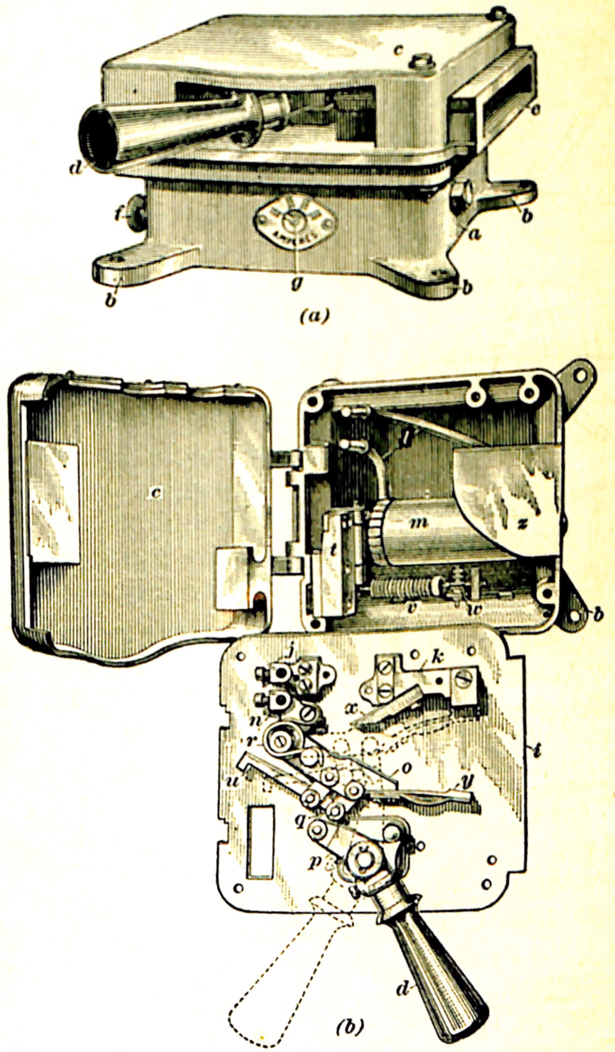


FIG. 34

breaker to open at a definite value of the current passing through it, and the index *g* shows on a scale the value of the current for which the circuit-breaker is set.

48. Action of Westinghouse Circuit-Breaker.—The arrangement of parts of the Westinghouse circuit-breaker is shown in Fig. 34 (*b*), in which the switch cover *c* has been thrown back, and the base *i*, which is of fireproof insulating material and carries the switch parts, has been removed. The trolley circuit wires are clamped into the terminal blocks *j* and *k*. A circuit is completed from *j*, through the leads *l* and blow-out coil *m*, to the terminal casting *n*, the switch arm *o*, and the terminal *k*, when the arm *o* is moved into the position of the dotted lines by the action of the handle lever *p* and togglejoint *q*. When the switch has been closed, the togglejoint is thrown past the dead centre, and the switch is held in a closed position by the toggle against the action of the spring *r*, which tends to open the switch. The switch can be opened by hand simply by moving the handle *d* to the right from the closed position until the togglejoint has passed its dead centre in the opening direction. The automatic features of the switch are obtained by the action of the rocking lever *t*, which is pivoted at its middle point, and one end of which acts as an armature of the blow-out solenoid *m*. When the switch is assembled, the lever *t* projects through a hole in the base plate *i*, and when the switch is closed, the lever *t* engages with a trigger *u*. If the current in the solenoid *m* reaches an excessive value, the armature of the coil is attracted against the compression of the spring *v* and the lever *t* pulls the trigger *u*, thus releasing the toggle and opening the switch. The adjustment of the circuit-breaker for different values of the actuating current is effected by a screw which alters the compression of the spring *v*, and the indicating pointer on the outside of the case is rotated by means of a worm and worm-wheel *w*. When the switch is closed, current passes from the arm *o* to the terminal block *k* through the laminated brush *x*; when the switch opens, arm *o* leaves brush *x* before the circuit is finally broken at the arcing finger *y*. By this means arcing is prevented from occurring at the main contacts, and is transferred to the arcing finger *y*, which can easily be renewed. A magnetic blow-out effect is obtained by means of a magnetic field set up by the blow-out coil *m* between the pole piece *z* and the cover *c* of the circuit-breaker.

49. Reliance Circuit-Breaker.—The general appearance of the Reliance circuit-breaker when the outside protecting cover is removed is shown in Fig. 35. The operating handle for opening or closing the switch is shown at *a* and the actuating coil and blow-out solenoid at *b*. The rocking lever *c*, one side of which acts as the armature of coil *b*, is the means of opening the circuit-breaker when the armature is attracted to the coil by an excessive flow of current. A flue *d*, in which any arc formed on opening the circuit can be extinguished magnetically, is provided at the top of the breaker.

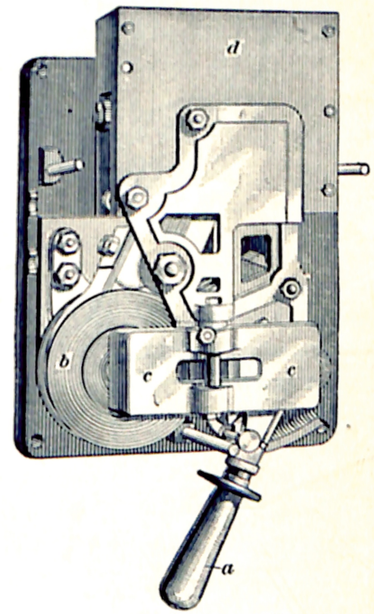


FIG. 35

50. Operation of Reliance Circuit-Breaker.—In Fig. 36 (*a*), (*b*), (*c*), and (*d*) is shown the actuating mechanism of the Reliance circuit-breaker. In views (*a*) and (*b*) the top plate *s* and rocking lever *t* have been removed, and are shown in views (*c*) and (*d*). View (*a*) shows the terminals of the circuit-breaker, to which the line wires are connected at *e* and *f*. From terminal *e* the circuit passes first through the winding of the blow-out coil *g* and thence, when the switch is closed, through the laminated switch blade *h*, the supporting lever of which is pivoted at the fixed point *i*, to terminal *f*. The switch may be opened and closed by the handle *j* through the links *k*, *l*, *m*, *n*, link *m* being pivoted at the fixed point *o*. The circuit-breaker is of the *loose-handle type*; that is, the handle is not connected rigidly to the switch blades, but only through links, which are arranged so that the switch cannot be kept closed so long as short-circuit conditions exist. Stability of the link mechanism is obtained, when the switch is closed, by means of the springs *p*, *q*; but when overload exists, the togglejoint *r* is knocked out in the

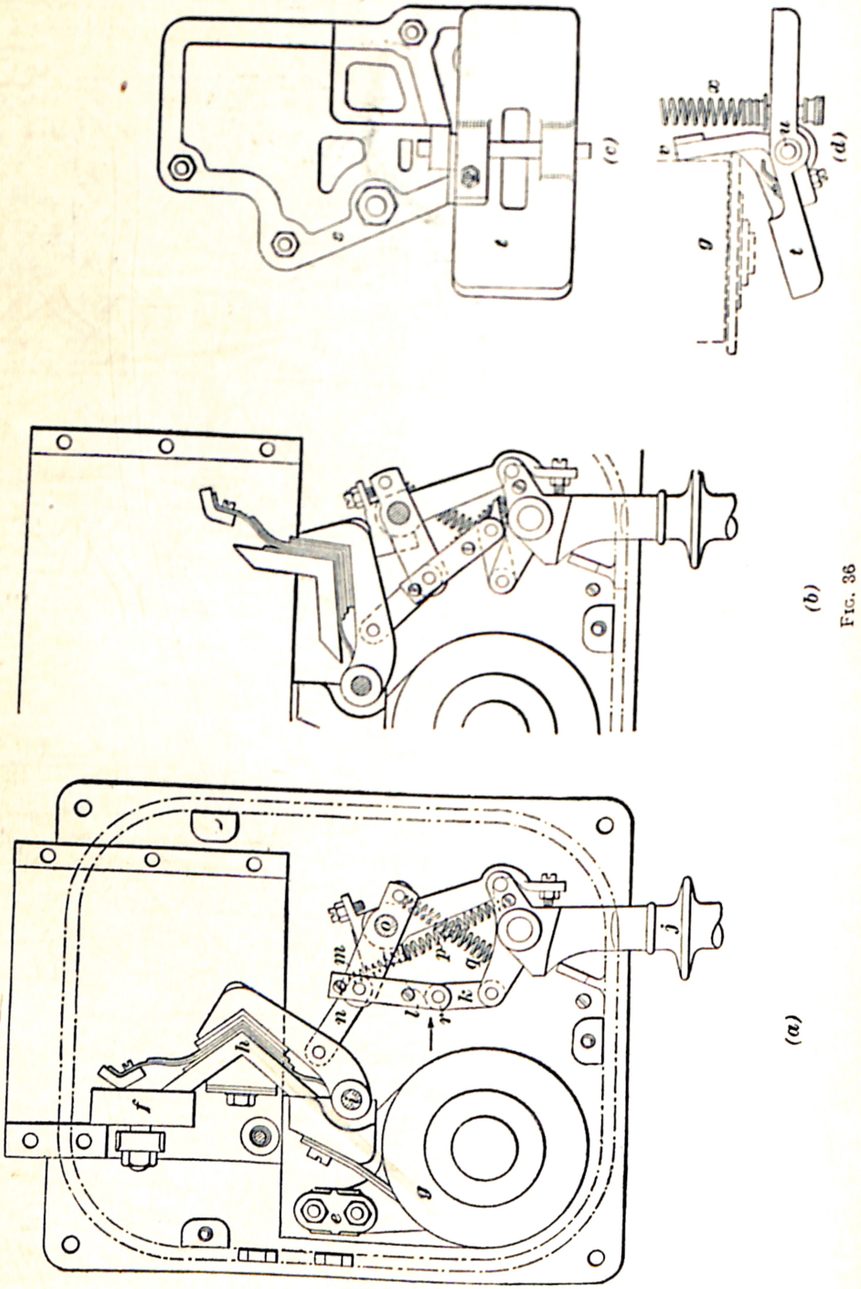


FIG. 36

direction of the arrow, and the links take up the positions shown in view (*b*), at the same time opening the switch, quite independent of the position of the handle *j*. The device used for tripping the switch is shown in view (*d*). The rocking lever *t*, pivoted at *u*, has a striker *v* projecting below it, and when excessive current in the blow-out coil *g* tilts the lever *t* against the opposing pull of spring *x*, the striker *v* comes in contact with the togglejoint *r*, view (*a*), and trips the switch.

FUSES

51. Fuses Versus Circuit-Breakers.—At one time, the fuse alone was used to protect motor circuits from excessive currents. On many tramway systems the circuit-breaker has superseded the fuse, because a circuit-breaker can be set with a greater degree of certainty, and it is much easier and quicker to close a breaker than to replace a fuse. Circuit-breakers kept in proper repair and adjustment are certainly more reliable than fuses. On some large systems there is a tendency to revert to the practice of using fuses, but only in conjunction with circuit-breakers, because in many cases of failure of the circuit-breaker the controller has blown up, with disastrous results. A circuit-breaker in series with a fuse is a good combination on a car, as the circuit-breaker is normally a better protection than the fuse, but the fuse will prevent accidents should a short circuit occur and the circuit-breaker fail to operate.

52. Westinghouse Car Fuse.—In Fig. 37 is shown a type of fuse box introduced by the Westinghouse Company. The two parts *a*, *b* of the asbestos-lined iron box are hinged together through a togglejoint *c*. They are brought together by raising the handle *d*. In the bottom half are copper terminals with **V**-shaped grooves *e*, into which a piece of copper-wire fuse of suitable length is dropped. Registering with the **V**-shaped grooves *e* in the bottom terminals are **V**-shaped tongues *f* in the top terminals. On bringing the top and the bottom halves of the case together, by raising the handle bar *d*, the two pairs of **V**-shaped jaws automatically clamp the fuse in circuit. The

advantages of this type of fuse box are the low cost of maintenance and the certainty and rapidity with which a fuse can

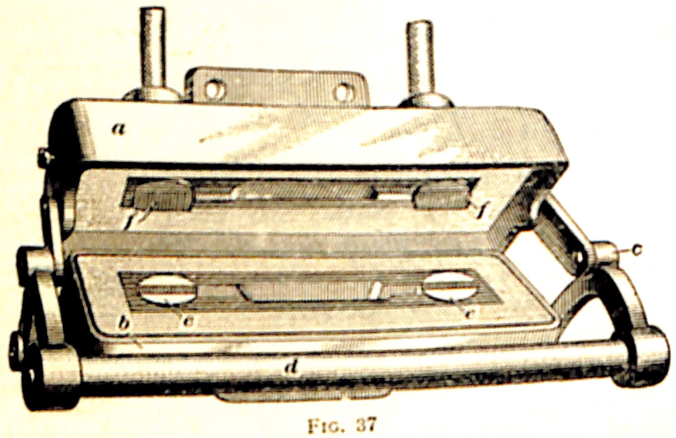


FIG. 37

be replaced without liability of shock; the lower terminals are dead when the case is open.

53. Enclosed Fuses.—In Figs. 38 and 39 are shown **enclosed fuses**, which are so called because the fuse wire is enclosed in a hollow cartridge *a*, Fig. 38, made of some tough fibrous insulating material and provided with copper heads or terminals *b*. The space surrounding the fuse is filled with finely divided powder, such as sand, which extinguishes any arc formed

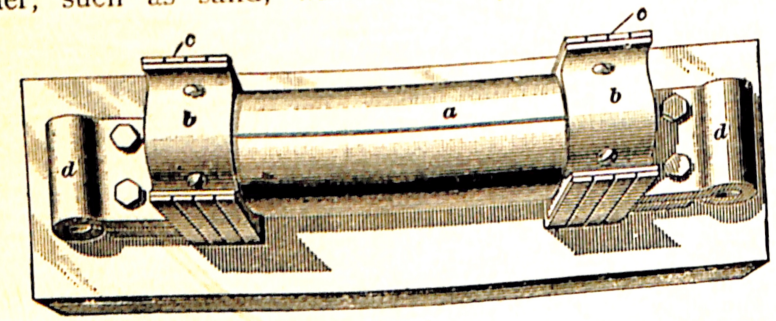


FIG. 38

by closing the passage, or a mixture of plaster of Paris and powdered borax, which, when the fuse melts, forms a flux with the molten metal, rendering it non-conducting and preventing the formation of an arc. The fuse cartridge is supported in spring jaws *c*, connected with terminals *d*, by means of which the fuse is connected in the circuit to be protected.

In Fig. 38 the parts are simply mounted on a slate base, but in Fig. 39 the whole device is enclosed in an asbestos-lined iron box *a*, provided with a lid *b* held closed by latch *c*. The trolley cable passes to the fuse-block terminals *d* through hollow insulating bushes *e*. Some enclosed fuses, instead of having contacts to fit spring jaws, have ordinary eye terminals that must be secured to their seats with screws. The screw connection is the more mechanical, but the spring-jaw construction is sufficiently safe and is much more convenient. To tell whether or not the enclosed fuse is blown, a small wire *f*, called the *telltale*, is sometimes connected in parallel with the enclosed fuse, but on the

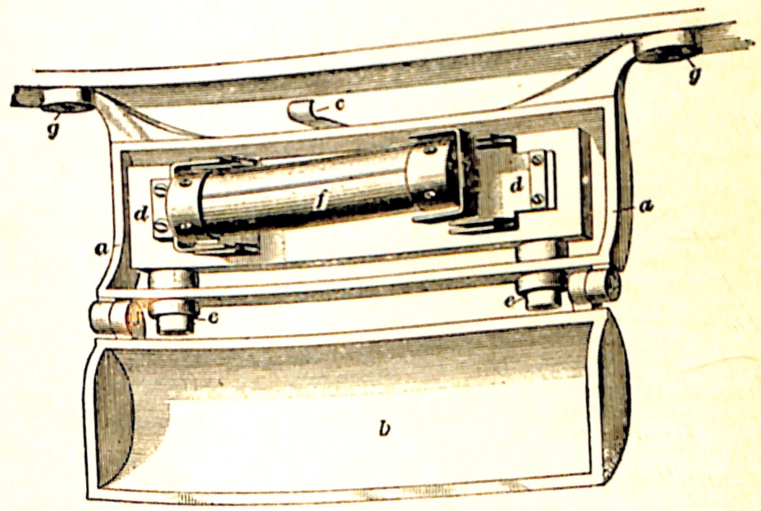
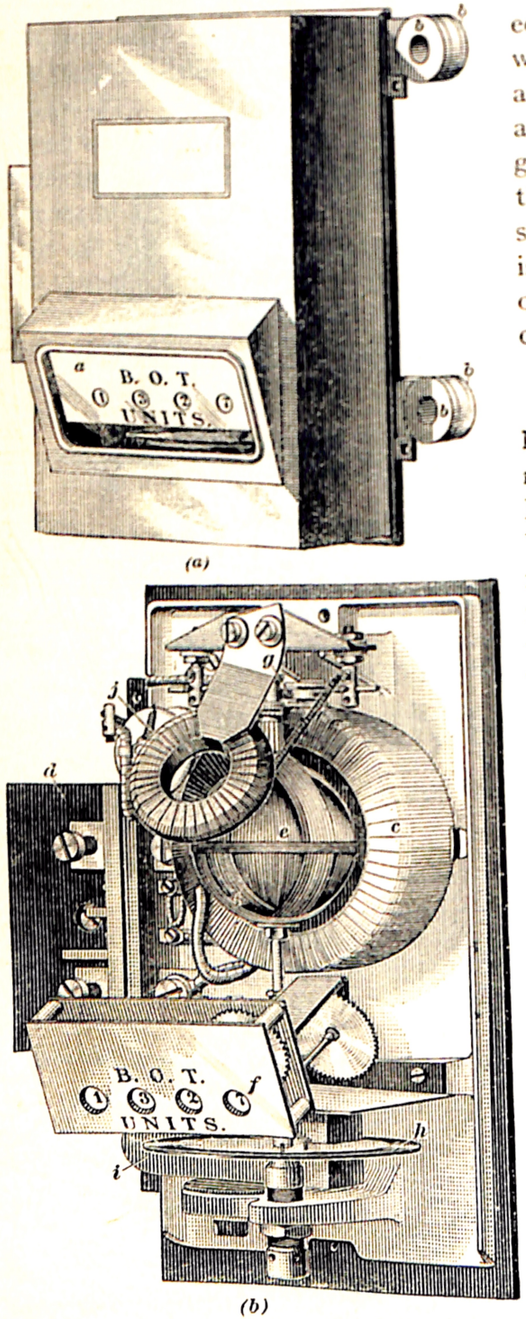


FIG. 39

outside of the cartridge. When the main fuse blows, the telltale burns out also. The enclosed type of fuse can be installed without danger of burning or shock by taking hold of the cartridge at the middle.

CAR METERS

54. Use of Car Meters.—It is the practice on some tramway systems to install a supply meter on every tramcar, and to keep records of the energy consumption, which can then be compared with the mileage run by the car. A check is thus kept on the general good condition of the car motors, controllers, gearing, etc., as well as on the skill of the driver in using the energy



(a) (b)

FIG. 40

economically or otherwise. The meters used are similar to stationary supply meters in general principle, but the arrangement and suspension of the parts is somewhat different, owing to the special conditions of duty.

55. Siemens Car Meter.—A Siemens car meter is shown in Fig. 40 (*a*) and (*b*). View (*a*) shows the meter complete, ready for mounting on the partition on the car. The consumption in Board of Trade units is registered in figures, and the reading can be observed through the window *a* in the cover of the meter. Rubber washers *b* are provided to cushion the meter when attached by means of screws to its support. In view (*b*) the cover of the meter is removed, showing the internal arrangements. The stationary coil *c* carries the main trolley current, the necessary

connections to the circuit being made on the terminal board *d*. An armature *e*, wound with a pressure winding and mounted on a vertical spindle, rotates in the magnetic field of coil *c*, and actuates the gear train of the counting mechanism at *f*. Current is led into the armature through the brushes and commutator *g*. The brake disc *h* and permanent magnet *i* provide the necessary retarding force to control the rotation of the meter. The jewelled bearings of the meter are spring-supported to protect the armature from vibration. The small fixed coil *j*, known as the *compensating coil*, is connected in series with the pressure winding of the armature and provides a magnetic field in the same direction as the current coil *c*, so that the meter will start with the smallest current in the main circuit.

LIGHTNING ARRESTERS

56. A car **lightning arrester** must be designed so as to extinguish automatically any arc due to the line current following the lightning discharge across the gap. It must be enclosed in a wooden box, in order to be protected from mud and water splashed up by the car wheels. Owing to the jolting and vibration to which it is subjected, the spark points of a car lightning arrester cannot be set for as small an air gap as on a stationary arrester, because of their liability to jolt together and produce a short circuit. No lightning arresters are needed on cars that run entirely in a tunnel or on a conduit system, but exposed trolley-line feeders and third-rail systems are protected in the usual manner. On ordinary tramcars, one arrester is used on the trolley end of the motor circuit, though two are better to ensure safety should one get out of adjustment. A lightning arrester having parts depending on gravity for action should be installed vertically. Where an external choking, or kicking, coil is used, or where a lightning arrester has three terminals, one of which leads to an internal choking coil, care must be taken to connect the lightning arrester so that the choking coil is in series with the motor circuit and not in series with the lightning-arrester air gap.

57. British Thomson-Houston Car Lightning Arrester.—The B.T.H. car lightning arrester, shown in Fig. 41, consists essentially of a single air spark gap connected up with a high resistance and a magnetic blow-out coil. A non-inductive high resistance limits the current that can flow across the air gap to earth from the supply system after a lightning discharge has passed; the leakage current passes round the blow-out coil in shunt with the resistance and produces a strong magnetic field that blows out the arc formed. The spark-gap terminals *a* are attached to the cover *b* of the porcelain box *c*; as these terminals are threaded, the length of the air gap is readily adjusted while the terminals are disconnected from the live circuit. When the cover *b* is on the box, the circuit is closed, the contact pieces *d*, *e* on the terminals fitting into spring contacts *f*, *g* in the bottom of the box; the blow-out coil *h* is connected in shunt with a part of the resistance and is furnished with pole pieces *i*, which set up a magnetic field to blow out any arc formed between the sparking terminals. The high resistance *k* is held in the contact clips *j* and *l*. The trolley wire is connected to the contact *f* and the earth wire is brought in to the clip *l*.

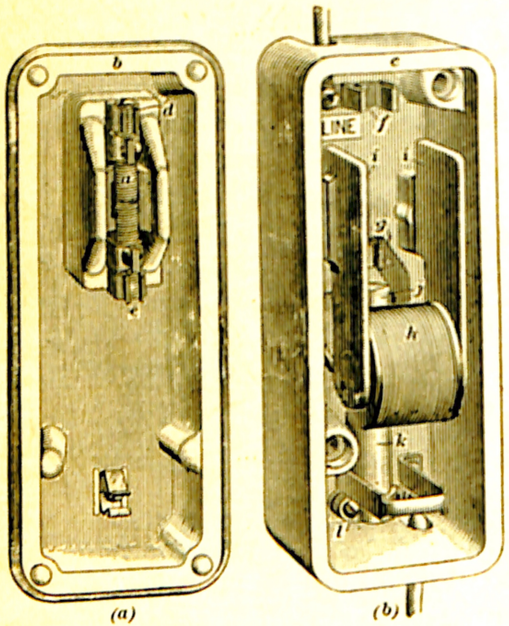


FIG. 41

LEAKAGE INDICATORS

58. Trolley-Standard Leakage Indicator.—In accordance with the Board of Trade regulations, an indicating device must be carried on double-deck cars without top covers, to give a warning

to the driver or conductor in case the trolley standard becomes electrically charged by means of a fault to earth on the trolley cable. This signal may be a red lamp which lights up if line current leaks to the trolley standard, or an audible signal such as a bell or buzzer. A special device developed for this purpose, known as the **Pringle trolley standard leakage indicator,** combines both an audible and a visible signal. In Fig. 42 (*a*) is shown the complete instrument; in (*b*) and (*c*) are shown the various parts when the cover has been removed. Under normal conditions the trolley standard is earthed through the leakage

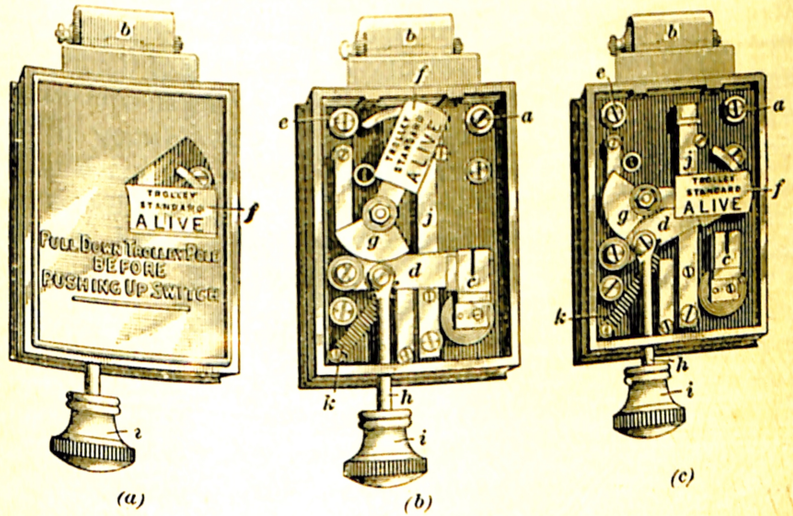


FIG. 42

indicator, the earthing wire from the standard being connected to terminal screw *a*, which is electrically connected through the buzzer *b* to the switch contact *c*, and thence through the switch blade *d* and a copper strip solenoid in the base of the indicator to the terminal screw *e* and directly to earth. As long as no current flows from the trolley standard to earth, through the leakage indicator, the indicating flag *f* is held in the position shown in view (*b*), and the earth connection cannot be broken, because the segment *g* attached to the flag *f* locks against the switch rod *h* to which the handle *i* is fixed, and prevents the switch blade *d* being opened.

59. Action of Pringle Indicator.—If the trolley standard becomes alive and an earth current, of any strength from a few amperes upwards, passes through the leakage indicator, the buzzer *b*, Fig. 42, sounds continuously, and the magnetizing current passing through the solenoid in the base of the instrument causes the armature *j* to be attracted toward the base. This releases the flag *f*, which drops to the horizontal position shown in view (*c*), and is visible through the window in the cover of the indicator, as shown in view (*a*). The switch blade *d* is kept closed by the tension of the spring *k*. On receiving the signal, the car must be stopped and the conductor must clear all passengers from the top of the car and remove the trolley arm from the wire, in order to break circuit. The handle *i* of the leakage indicator may then be pushed up, to open the earth connection, and the car driven to the depot for repairs. The danger-indicating flag remains in the horizontal position, and a catch interlocks the flag *f* and switch blade *d*, keeping the switch open, as shown in (*c*), until the necessary repairs are effected and the indicator is reset.

CAR WIRING

POWER WIRING

60. Power Circuits.—The connection of the various items of electrical apparatus on a tramcar is comprised in the **power wiring,** which includes all the motor circuits, and the **lighting wiring,** which deals with the circuits for external and internal lighting and illuminated signals. The actual arrangement of the power circuits varies with the type of equipment and the particular form of the apparatus used on the car. The most common case is the wiring of a car driven by two motors, which are controlled by one of two controllers, one of which is placed at each end of the car. A diagram of the wiring for one such wiring arrangement is shown in Fig. 43. The controllers *No. 1* and *No. 2* are placed one on each platform of the car, and all wires which are common to both controllers are grouped into two canvas hose *a*, *b*, which are carried from platform to platform under

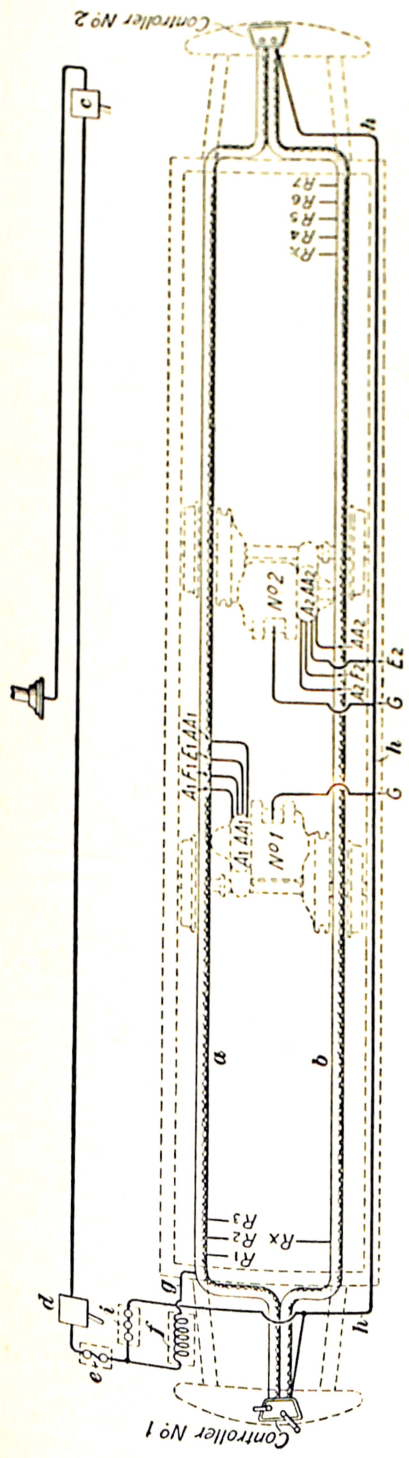


Fig. 43

the car seats. One hose *a* also contains a trolley cable, which is connected to the cable in the trolley standard through the canopy switch *c*, circuit-breaker *d*, car fuse *e*, and kicking coil *f*. The wire *g* leading from the kicking coil *f* to the hose *a* is termed the *trolley tap*. Various tappings are taken off the wires in each hose. From hose *a*, tappings *R1*, *R2*, *R3* are made to one frame of the car-starting resistance, under the floor of the car, while the tappings *A1* and *AA1* are connected to the armature leads of motor *No. 1*, and *F1* and *E1* to the field leads of that motor. Since the commutators and terminals of the two motors are on opposite sides of the car, all the other wires are placed in hose *b*. The tappings *Rx* are joined to the end of one part of the car resistance and to the beginning of a second portion, slung under the other end of the car. Tappings *R4*, *R5*, *R6*, and *R7* are connected to this second resistance. Tappings *A2* and *AA2* are connected to the armature leads of motor *No. 2*, and *F2* to one field lead of motor *No. 2*. A *ground*, or *earth*, *wire h* is also taken from one controller to the other, outside the canvas

hose. To the ground wire are connected the earth wire of the lightning arrester *i*, and the field lead *E2* of motor *No. 2*, while the ground wire is itself earthed on the frames of the two motors by tappings taken off at the points *G*.

CAR-LIGHTING WIRING

61. Arrangement of Lamps.—The lighting circuits on a car include the lamps for lighting the interior, the conductor's platform light, the dash or head light, and the lamps for illuminating the destination indicator. The Board of Trade also require a red light to be shown from the rear end of the car. This is usually arranged by fitting a red lens in the end partition of

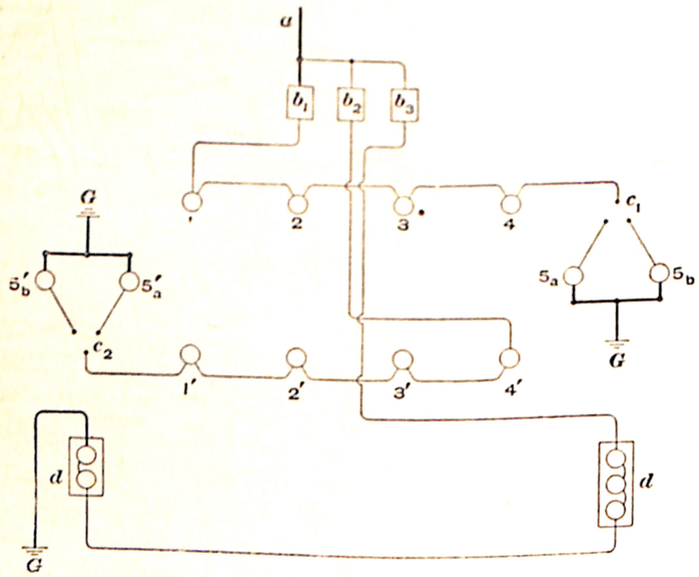


FIG. 44

the car and placing one of the inside lamps so that it will illuminate it. The dash or head light is only required on the front of the car when travelling, and the conductor's platform light only at the rear end, so that, as the car usually reverses at a terminus, arrangements must be made by means of three-point switches to light either the dash or the conductor's lamp at either end of the car. By this arrangement both dash lamps

may be lit in the case of fog, but when both dash lamps are lit the conductor's lamp is out.

62. Diagram of Connections.—There is no standard method of lighting a car, the lighting being suited to the requirements of each case, but in Fig. 44 is shown a common method of lighting a large double-deck car without top cover. In the case of top-covered cars an additional circuit of lights would be run. As the available trolley-wire pressure is 500 volts, the lamps are connected in circuits of five 100-volt lamps each. The wire *a* is a tapping from the trolley cable and is connected to the switches, or combined switches and fuses, b_1, b_2, and b_3. The switch b_1 controls the inside lamps *1*, *2*, *3*, and *4*; the fifth lamp in the circuit is either the conductor's platform lamp 5_a or the dash lamp 5_b according to the position of the three-point switch c_1. The circuit is grounded on the earth wire of the car at the nearest point *G*. Switch b_2 controls a similar circuit, consisting of lamps *1′*, *2′*, *3′*, *4′*, and $5_a'$ or $5_b'$, on the other side and end of the car, which are controlled by the three-point switch c_2. The red lenses which show the red rear light may be placed in front of lamps *1* and *4′*. Switch b_3 controls the two illuminated destination indicators *d*, three lamps being placed in one box and two in the other. The backs of the destination boxes are fitted with bull's-eyes, so as to light the top of the car.

CAR DEPOT

ARRANGEMENT OF CAR SHED AND REPAIR SHOPS

63. Location of Depots.—All cars are stored in depot car sheds at night or when not required for use; repair shops are usually connected with the depot to receive cars in the case of breakdown or for carrying out the ordinary maintenance repairs. In the case of a scattered district, it is not advisable to store all the cars in one shed, as this means a great waste of time in running out to the various districts when starting and returning from work. The *dead mileage* which is run means extra running

costs and wages. In these cases it is usual to have several car sheds in convenient places, with a central depot and repair shop, only light repairs being done at outlying depots, the heavy work being sent to the central repair shop for repairs.

64. Methods of Handling Cars.—The car shed may be entered from the tram lines on the main roadway by means of radiating and branch lines, forming a *fan*, or a double line may run directly into the car shed, and the cars distributed to the different lines inside the shed by means of a *traverser*. The fan entrance is suitable for small sheds, in connection with the overhead system of running, but in the case of large sheds, especially if in connection with the conduit system, complication is to a great extent avoided by the adoption of the traverser. A motor-driven platform at the floor level runs on rails laid in a pit across the car shed from one side to the other. As the cars come in they are run on to the platform, and traversed to the siding in which they are to be berthed, where they are run off.

65. Car Pits.—All the lines of rails in a car shed are arranged with pits between the rails under the cars, so that the car trucks and motors can easily be examined from below, and adjustments and small repairs easily carried out. The car pits should be from 4 to 5 feet deep, and are sometimes simply dug out and bricked at the sides. A better method is to excavate the whole area and lay a concrete floor, at a sufficient depth to form the bottom of the pits ; the car rails are then laid on brick or cast-iron pillars, and a wood or reinforced-concrete floor is built between adjacent car sidings.

CAR REPAIRS

66. In small tramway systems, where there is only one depot and car shed, it is usual to have a small machine shop to deal with the necessary repairs. In large systems having many depots, the central repair shop handles the heavy repairs, such as are caused by serious collisions, and is also capable of thoroughly overhauling each car about every 12 months. The ordinary maintenance work carried out in the local depots includes

keeping all truck bolts tight, adjusting hand brakes, changing armatures, renewing bearings and pinions, changing flatted or worn-out wheels, repairing lights, bells, and trolleys, cleaning and repairing controllers, also the nightly cleaning of the cars. The work of replacing wheels in the depots is greatly facilitated if the pits are so constructed as to allow a short piece of rail to be taken out so that the wheels may be lowered into the pit by means of a jack.

67. General-Overhaul Shop.—The central repair shop usually includes a general-overhaul shop, a woodworking shop, blacksmith shop, paint shop, winding shop, and machine shop. A thorough annual overhauling is of very great importance to the successful running of the rolling stock. When the car comes in, the trucks are removed from the car body and the body is handed over to the bodymakers and painters for renewal of any woodwork and repainting, where necessary. The motors are removed from the trucks and the trucks are squared up and all brake-lever pins replaced where worn. Springs are renewed or set up, and the wheels, journal boxes, and bearings are attended to. The motor case is opened and the armature taken out ; the motor case is cleaned and the field coils and connecting leads examined and painted with an insulating paint. The commutator is trued up, the armature is painted over, and the bearings renewed.

68. Woodworking Shop.—The essential tools in the woodworking shop are a circular saw, a band saw, a mortising machine, and a planer. This shop deals with the repairs to floors and roofs and any repairs to panels damaged by collisions.

69. Blacksmith Shop.—The blacksmith shop is fitted with the usual blacksmiths' tools, forges, and anvils, and deals with the straightening of truck stays, welding new ends on brake rods, and the many small repairs to the wrought-iron work on the cars.

70. Paint Shop.—The paint shop must be carefully enclosed from the other shops and kept clean, so as to prevent dust from settling on newly varnished cars. It should also be warmed by

hot-water pipes, so that the paint may dry quickly. Platforms or trestles should be erected alongside the cars, so as to render the upper portions easily accessible.

71. Winding Shop.—The winding shop must also be enclosed from the overhaul and blacksmith shops. It should contain the repair stands for the armatures, a banding machine, and a coil-winding machine, with formers for the various coils used, also a stove for drying out the armature and field coils. All defective armatures, field coils, and commutators are repaired in this shop; also the various cables used on the cars are repaired in it.

72. Machine Shop.—The machine shop contains the usual engineers' tools, drilling machines, planing and boring machines, a metal saw, and lathes for turning bearings, steel-tired wheels, and commutators. The emery grinder and wheel press are usually placed in an annexe where the wheels can be easily handled.