and dust proof, and with proper attention is a very durable piece of machinery (fig. 10). Although the standard design of motors is at present based on a single-reduction gearing, there are in operation traction-motors which are not geared.

On the locomotives used on the New York Central, the New York, New Haven & Hartford, and the Baltimore & Ohio railways in America, the City & South London railway in England, the armatures surround the driving axles. In all the cases mentioned, except the Baltimore & Ohio railway, the armatures are set directly on and solid with the axles of the driving-wheels, while on the Baltimore & Ohio locomotives the motors are sleeved on the axIes, there being a slight play between the sleeve and the axle, which allows a flexible support. The wheels arc driven by arms projecting from the armature shaft.

There is no fixed method of rating the output of traction-motors. Most manufacturers, in giving a certain horse-power capacity, mean that at the given rating the motor will run an hour with a rise in temperature of a certain number of degrees, not that it can be run continuously at the power given. Another system of rating depends on the draw-bar pull which the motor can develop under normal conditions of voltage and speed. Uniformity is greatly needed.

One of the most important parts of the equipment of an electric car or locomotive is the controlling device. In the early days of electric traction a number of different methods of regulating the speeds of the cars were used, but they have been reduced to practically one standard method. In the old Sprague system there were at first no resistances outside of the motors themselves, but the field coils of the motors were divided into sections, and by changing the relative connexions of these sections the total resistance of the circuit could be changed; at the same time the strength of the field for a given total current was either increased or decreased. In other systems the fields and armatures of the motors were not changed in their relation to one another, but external resistances were cut out and in by the controller. Usually there are two motors on each car, and it is evident that if the speed of a car be changed within wide limits, all the other factors remaining constant, there will be a very considcrable loss by either of these methods of regulating, unless the relative connexions of the motor armatures can be changed. This can be done by putting the two motors in series where low speed is desired, and in parallel where the speed is to be increased. This method was tried in the early days of electric traction at Richmond, and discarded, but it has been again taken up, and is now the standard method of regulation in ordinary tramway work. Roughly speaking, when the car is started the controller connects the two motors in series with an external resistance, then cuts out the external resistance, then breaks the circuit, then connects the two motors in parallel. The external resistance is put again in series with them, and then is gradually cut out as the car speed increases. By this method a considerable range of speed is attained at a fair efficiency. The controller (fig. 11) consists of a cylinder having on it a number of copper segments so arranged that on rotating it different connexions are made between stationary fingers that bear on these segments. In the first types much difficulty was experienced from the burning of the segments and fingers, due to the sparking on breaking the circuit, but this has been to a large extent obviated by using magnetic blow-outs at the point of break. (A magnetic blow-out is simply a magnet so arranged that the arc caused by breaking the circuit takes place in the magnetic field.) There is a reversing lever on the controllers separate from the controller handle, and interlocking with the controller so that the reverse lever may not be moved except when the controller is in the “off” position.

When it is desired to run trains of cars and to accelerate them rapidly, it is sometimes necessary to have more than one car equipped with motors. In this case all the motors must be controlled from one point, and a number of ingenious devices have been evolved to accomplish such “ multiple control.” In general, each car has its own controller, and all the controllers are operated by electric power from switches on each platform of any of the motor cars.

A motor and controlling system designed to save and utilize the power produced by a car running down an incline has been developed and is termed the “regenerative system.” A car run- ning over a line having heavy grades must have sufficient energy given to it to overcome its frictional resistance to motion and also to lift the weight of car and load from the bottom to top of each up-grade. On the return trip, the car “ coasts ” or runs down the grade without the consumption of current, but is restrained from attaining too high a speed by the brakes, thus wasting the energy existing by reason of the position of the car.

With the regenerative system the motors are caused to act as dynamos which arc driven by the motion of the car axles when descending a grade, and, as they are connected to the line by the trolley or contacting device, the current thus generated is fed to the line and may assist other cars climbing grades at some other point on the system. The delivery of electrical energy also puts a resis­tance on the car axles and produces a braking effect which almost automatically fixes the car speed. If the speed be too high, the excessive current generated will tend to retard the car and reduce its velocity, while if too low the small current produced will set up but little opposition to motion and the car will accelerate.

Obviously, series motors cannot be used for this service. The motors have shunt fields, and their speed is varied by varying the field strength. Motors of this type are larger, more costly and slightly less efficient than series machines, so that a regenerative system has no place on roads that have a fairly level contour. When, however, the grades are frequent and excessive, the power saved more than counterbalances these factors, and the system may prove a valuable one for such service.

For tramcars of ordinary sizes hand-brakes are used, these being generally spindle brakes, with leverage enough to handle the com­paratively heavy cars. When the size and speed of the car increases, however, these hand-brakes do not give sufficient control, and power brakes have to be adopted. Of these there are several forms that have proved successful in practice. the one most extensively used in electric railways is the air-brake, which is similar in its mechanical operation to the air-brake used on steam railways. The compressed air required for the operation of the brake is obtained by means of an air-pump driven by an electric motor, the circuit of which is controlled by a switch actuated by the pressure of the air in the receiving tank. When this pressure rises to a predetermined value, the device acts and interrupts the supply of current to the motor, which is thus stopped. When the pressure falls below a determined minimum the device operates in the opposite direction, and the motor and pump start. Of electric brakes there are several varieties. One type consists of two iron disks, one keyed on the axle but capable of moving along it a short distance axially, and the other held firmly on the frame of the truck. By means of a coil, set in a recess of annular form turned in the face of the fixed disk, the disks are magnetized transversely, and are drawn together with greater or less pressure, dependent on the amount of current that is allowed to pass through the coiI. It is customary to arrange the current connexions in this form of electric brake so that when the handle of the controller is turned beyond the stopping position the current is cut off from the source of supply, and the motor running as a dynamo furnishes the current to work the brake.

The magnetic track-brake, which is sometimes used on tramway cars, consists of a pair of steel shoes, suspended from the truck frame and hanging near and over the rail, a steel yoke connecting the two shoes together. On this yoke is wound a heavy magnetizing coil which, when energized, strongly magnetizes the two steel shoes and causes them to draw against and adhere to the track. Bracing links connect these track shoes with brake shoes on the wheel rims, and the drag of the track shoes thus applies pressure also to the wheel shoes. The downward pull of the track shoes gives a greater pressure of the wheels against the track than that due to the weight of the car, and the sliding or “ skidding ” of wheels, with the consequent production of flats, is avoided. A further braking effect comes from the use of the motors as dynamos, driven by the motion of the car, to supply current to the brake magnetizing coils. This therefore is one of the most effective brakes that has been devised. It has, however, not been very extensively used owing to its high cost and difficulties that arise from the track shoes running so close to the rails that any uneven places—frogs, switches, crossings and the like— may rub against them and give a braking effect at times when the car is accelerating or running. A pair of shoes is applied on both sides of the car, one pair being hung over either rail.

Another method of braking is by arranging the connexions of the two motors so that one acts as a dynamo driven by the motion