installation of this character to be made was in Washington, D.C., U.S.A., where a considerable system of street railways was changed from horse operation to this new method. The success of this system, and of experiments made on Lenox Avenue, in New York City, led to the construction of many miles of railways of the conduit type in the latter city. It is also used extensively in London. (For details of the construction of the conduits, see Tramway.) This system is much more expensive to install than the overhead trolley system, but experience has shown that it can be as economi­cally operated. Most of the troubles that have occurred have been due to lack of experience, but on the whole they have not been more serious than those experienced with overhead systems.

The great expense of the open conduit has led numerous inventors to bring out systems of operating electric railways by means of closed conduits or sectional third rails, in which the working-conductor îs laid on the surface of the ground between the rails, and is connected with the source of current only as the car passes over each section. In this way the immediate section or portion of the working-conductor under the car is electrically active, but other sections arc not, and all danger to the passage of street traffic is removed. Up to 1900, nearly one thousand patents for this type of street railway construction, known also as the “ surface contact ” system, had been granted by the United States patent office alone. So far the system has been introduced in but few places, but its performance has been more than promising, and it is thought that it will be more extensively adopted in the future. Among the more important railways at present equipped with it may be mentioned one in Paris, using the Diatto system, and one at Monte Carlo, where the Westing- house system is installed. In both these the current is supplied by means of “ buttons ” or metallic disks laid flush with the surface of the street between the tracks, and connected through switches to a working-conductor. Under the car is installed a current- taking device in the shape of a long runner or skate, which runs over the buttons and is appropriately connected with a storage battery on the car, so that when it touches one of the buttons current is sent from the battery through a system of electro-magnets operating the switches which connect that particular button to the feeding system, and thus the runners are enabled to receive current for the operation of the motors on the car. The various systems differ in the method of connecting the contact rail or button with the live conductors; in some a magnet on the car works a mechanism to make the desired contact, in others a current from batteries on the car actuates a switch located near the track. (See Tramway.)

The third-rail system, which is a development of the overhead trolley and track-return system, has been applied to several large and important railway installations, especially in the United States, and in the prolongation of the Orleans railway in Paris from the Place Valhubert to the new station at the Quai d’Orsay. Its name almost sufficiently indicates its method of operation. A rail similar to the track-rails is laid upon insulators and forms the working-conductor. On the elevated railways in New York, Brooklyn, Boston and Chicago and the subway in New York, a pressure of about 600 volts is used between this rail and the track-rails which form the return circuit. Contact is made with the third rail by means of a bronze or cast-iron shoe, either resting upon the rail by its own weight, or pressed down upon it by springs. This is generally attached to some part of the truck of the car in preference to any part of the body of the car, so as to avoid any vibration or swaying due to the movement of the body upon its springs. The third-rail system has been adopted in many instances where large and powerful trains are to be operated on private rights of way, but it is nowhere in use for electric traction upon highways or in streets where there is any passing of foot passengers or vehicles. An excellent example of such construction may be found in the Albany & Hudson railroad, which connects the city of Albany with the city of Hudson, in New York state. Here the length of the road is about 32 m., the track being of standard gauge and laid with a 60-lb T-rail. A T-rail of the same size, raised about 1 ft. above the level of the running-rails, is used for the electrical conductor, and is installed on insulators situated 5 ft. apart on the ends of the cross-ties. All these rails are well bonded with copper bonds at the joints. At road crossings, which on this railroad are at grade, the third rail is omitted for a distance nearly equal to the length of a train. Appropriate cast-iron shoes, fixed to the trucks of the front and rear cars of a train, bridge the space, so that the forward shoes are running on the rail past the break before the rear shoes leave it. Upon this railroad motors of considerable size and power are used, and both passengers and freight in their original cars, as received from connecting steam railways, are transported. Other examples of third-rail construction occur in the extension of the Baltimore & Ohio railway tunnel at Baltimore, the New York Central Railway Company’s New York terminal, the underground systems of the City & South London railway, the Waterloo & City railway, and the Central London railway in London, and the Versailles division of the Western railway of France. In some cases, as on the Metropolitan, the District, and several of the “ tube ” railways in London, the running-rails arc not used for the return circuit, which is completed by a fourth rail similar to the conductor rafl, laid outside the track.

One of the oldest forms of electric traction is by accumulators. In brief, its principle is that storage batteries, or accumulators, are carried on the car, which becomes a veritable automobile. It has been the usual practice to instal about 80 cells, giving a pressure of 160 to 175 volts at the motors; these are recharged after the car has run about 25 111. In general, the accumulators are not charged in place, but the car is supplied with a new set, fully charged, at the end of a run of about the length mentioned. The system has been installed in a very large number of places in Europe and America, but has never shown the gratifying commercial success which the direct-conduction systems exhibit, on account of the high cost and depreciation of storage batteries. In some places, notably in Hanover, Germany, where legislative ordinances have forbidden the overhead conducting system in city streets, a combination has been used whereby accumu­lator cars run in the city districts from the energy stored in their batteries, and in the suburbs operate directly as overhead trolley cars, the batteries being charged at the same time from the over­head system.

*Alternating Current Systems.—*Alternating current systems are now being used, both single-phase and three-phase. In the former case the newly-developed single-phase motors, later to be described, are employed, while with three-phase systems induction motors are used. The polyphase current is much used as a means of distributing energy from a central power- station over extended lines of railways, but is generally converted into direct current through the agency of rotary converters, and fed to the lines as such. There are, however, a few railways working directly with induction motors upon a three-phase system of supply. Prominent among these may be mentioned the Valtellina railway in Italy and the Jungfrau railway in Switzerland. Upon these lines the rails arc used as one of the three conductors, and two trolley wires are suspended above the track. The locomotive is provided with two trolleys, one running upon each wire, and consists simply of an induction motor coupled through appropriate gearing to the mechanism of the truck. For starting a large resistance is introduced into the rotor or secondary circuit of the motors by means of collecting rings placed on its shaft, upon which bear brushes. This resistance is cut out as the speed increases, until it is all withdrawn and the rotor is short-circuited, when full speed is attained. It has been found that potential differences of about 500 volts in each phase can be safely handled, and it is claimed that the few railways which use polyphase currents have shown gratifying results in practice.

In the early years of the 20th century single-phase alternating current motors for electric traction were developed, and single-phase systems were extensively installed both in Europe and in America. the simplest type of single-phase motor is a series motor provided with the usual commutator and brushes, in which the current passes through both the field coils and the armature coils. The armature and field windings being traversed by the same current, the reversal of the field magne­tization and that of the direction of current flow in the armature are coincident, so that the turning effort or torque, on the armature current produced by the interaction of armature and field magnetization is always in the same direction. Since the alternating current passes through both members of the motor, the armature and field cores are both laminated. In the later types of these motors the field coils are distributed and embedded in the field ring, so that the inner surface of the field ring presents a practically smooth surface to the armature. Troubles were at first experienced with commu­tation of the heavy alternating currents required for the operation of these motors, vicious sparking taking place at the brushes. This was overcome by the use of auxiliary or “ compensating ” coils, which are embedded in the field magnet ring, being placed between successive magnet coils. These compensating coils are usually connected in series with the main armature and field circuit. They may each, however, have, their two ends joined together, (short-circuited), the currents in them being induced by the alternating magnetic flux of the fields.

Motors of the above types have the general characteristics of direct current series motors, and possess the same general relations between speed and torque that are such an important element in the success of direct current series motors. The efficiency of alternating current motors is not quite so good as that of direct current motors, on account of the rapid reversal of the iron magnetization in the field magnets, but their efficiency is high and their performance in practical work has been excellent (fig. 8).

There is another type of single-phase motor that has been used in Europe, but not in America, which is commonly called the repulsion motor. In these motors the armature is not directly included in the main circuit, but opposite points bn the commutator are connected together through brushes. The working current is fed to the field magnets, and the rapid reversals of magnetization induce currents in the armature coils, which currents, working with the field magnetization, cause rotation. Several types of repulsion motors have been developed, and in general their characteristics are similar to those of the plain series type. They have not, however, come