must be heavy enough to grip the rails, and the whole weight to be drawn is then considerably greater.@@1

II. Conductor systems, which may be classified thus:—

(a) Those using the ordinary rails as the only conductors. The lines at Lichterfelde and Brighton, already mentioned, are exam­ples of this plan, which is quite inapplicable where the rails are laid flush with the roadway as in city streets.

(5) Those using a third (insulated) rail, above ground. To this class belong the Portrush, the Bessbrook, and several American lines. This plan, like the last, is not applicable to city streets.

(c) Those using one (or in some cases two) overhead conductors. A line of this type has been successfully worked between Mödling and Hinterbrühl, near Vienna, and another between Frankfort and Offenbach, both since 1884, at a cost of about 3½d. per car-mile. The conductors consist of slotted tubes 1 inch in bore supported on posts 18 feet high and stayed by wires at intermediate points to keep them from sagging. The contact carriages are pistons sliding in the tubes.@@2 The Daft lines at Baltimore and other places in America, and the Van Depoele lines, of which some 30 miles are in operation, are mostly worked by means of overhead conductors.

*(d)* Those using underground conductors in a slotted channel or conduit. This system, which has the obvious advantage that the conductor is placed entirely out of the way of street traffic, has been introduced at Blackpool by Mr Holroyd Smith, and, in America, at Cleveland by Messrs Bentley and Knight and at Philadelphia by Mr Schlesinger. In the Blackpool line the conductor is split into two parts which run parallel to each other within the conduit on its two sides, and are touched by a contact arm which reaches down through a narrow central slot at the level of the street; an electromotive force of 200 volts is employed. The conduit is placed midway between the rails, but it may be questioned whether, in view of the conditions of ordinary street traffic, a better place for it would not be at one side. Mr Field has proposed a tramway with two conduits, one beside each rail, containing two conductors, one to be charged positively and the other negatively, so that a comparatively high resultant difference of potential is available for the motor although the potential of neither conductor differs to a dangerous degree from that of the earth.

(*e*) One system remains to be described, which was proposed in 1881 by Messrs Ayrton and Perry as specially applicable to electric railways of considerable length, in which an exposed conductor would give rise to much loss through leakage. Their plan is to use a well-insulated conductor in a closed channel underground. The line is divided into short sections; each of these has an exposed conductor, which may be one of the rails, and this is placed in temporary contact with the insulated conductor as the train passes, by the pressure of the wheels on a flexible rail or stud, or by means of automatic electromagnetic switches. Leakage is thus restricted to the continuous and well-insulated conductor, together with that section of the surface conductor which is in contact with the former at any one time; and the system has the further advantage that it gives the means of providing an automatic block by which suc­cessive trains are kept from overtaking one another.

The form and disposition of the motor-dynamo and the mode by which it is connected with the driving-axle of the car are matters in which much variety of practice exists. The question of gearing is complicated by the fact that the frame of the car oscillates verti­cally with respect to the axles. Spur-wheels, worm-gear, friction­gear, belts, multiple-band gear, and chain-gear are or have been used. Mr Reckenzaun’s car is carried by two bogie trucks, one under each end, and each bogie carries a motor whose axle, placed longitudinally, drives a central spur-wheel on one axle of the bogie by means of a worm. An advantage possessed by two motors is that, by coupling them in series or parallel, or by using one only, the driver is able to command different grades of power without the use of resistance coils. In cars driven by storage batteries the same object may be secured by various groupings of the cells.

*Telpherage.—*In all the methods of electrical traction to which reference has been made the road on which the cars run is essen­tially a railway or tramway of the kind used in horse traction and steam traction. In 1881 the late Prof. Fleeming Jenkin devised a system of electric locomotion in which the vehicles are hung upon what resembles an exaggerated telegraph line. To this he gave the name of *telpherage.* As developed by the inventor, in conjunction with Messrs Ayrton and Perry, the system is especially adapted to the transport of goods at a slow speed, in localities where the traffic would be insufficient to support an ordinary railway.

The telpher line is a steel rod or cable, suspended from brackets on posts about 70 feet apart; it serves at once as carrier of weights and conductor of electricity. The line may be made rigid, and in that case a high speed of transit may be attained; but in general the line is flexible and the trains travel slowly in what may be, if the

volume of traffic requires it, a nearly continuous stream. Each train consists of a series of buckets or skeps which hang each from a single running wheel or pair of wheels, and are spaced by wooden connecting bars. A small electric motor, which hangs below the line and is geared by spur and chain gearing to a pair of driving­wheels, forms the locomotive. In general, the line is electrically divided into equal sections, which have the same length as a single train, so that the front carriage is always on the section in advance of the rear carriage. The train is furnished with a continuous conductor from end to end, through which it makes electric con­tact between the section in front and the section behind, and the motor is included in the circuit of this conductor. Two systems of working are used, which enable trains to be run either in electrical series or “parallel.” In the series system the successive sections of the line are electrically connected, so long as no train is on them, by means of switches at the joints between the sections, so that the whole forms one continuous conductor. When a train comes on any one section it breaks contact at the joint between that section and the one behind it; the circuit, however, remains closed through the conductor on the train itself, and in this way the motor receives the current which is passing through the line. Other trains at other places in the line receive the same current, each by breaking for the time the ordinary contact between the two sections it touches, and substituting a contact through its own conductor and motor. When a train leaves a section it replaces the switch that makes contact with the section behind. If, how­ever, there are more than one train on the line, an automatic block system is added to prevent one from overtaking another by letting the section which a train leaves stand insulated for a time. No control is exercised from the vehicles themselves; in fact, the trains run without attendants. In the simplest parallel system of tel­pherage a continuous conductor distinct from the line is stretched alongside of it; the trains make contact between the two. The figure shows another plan, known as the cross-over parallel system,

which is suitable where a double line of trains is desired. There A1, B2, A3 . . . form successive sections of one line, and B1, A2, B3, ... of another. A1, A2, A3 . . . are electrically continuous, and are connected to one pole of the dynamo. B1 B2, B3 . . . are also continuous, and are connected to the other pole. Thus the sections of each line are alternately positive and negative. Any train, such as P or Q, bridges the gap between two sections and receives a current which suffers reversal as the train passes from one section to the next. It is to be regretted that space does not admit of any description of the details of telpherage, many of which present the utmost ingenuity. The system was shown to be practicable by experiments on an experimental line at Weston. The first telpher line on a commercial basis was erected in 1885 at Glynde, in Sussex, and has been maintained in operation notwithstanding many diffi­culties inseparable from so completely novel an undertaking.

The electrical propulsion of boats, by means of storage batteries, has been the subject of several successful experiments, but has not found systematic application. In this connexion reference should be made to a scheme proposed by Ayrton and Perry for the haulage of boats on canals or of waggons upon roads. Their proposal was to have a conductor ranged along the towing path, or along the side of the road. A motor running on this was to pull itself along and drag the boat or waggon after it.

In aerial navigation, storage batteries working an electric motor have been used to drive the propeller of a “dirigible” balloon.

Space does not admit of more than the briefest reference to the theory of electric motors. A motor may be regarded as a dynamo acting to produce an electromotive force *e* which is opposite in direction to the externally impressed electromotive force E. The resultant electromotive force is E - *e,* and on this, together with the resistance of the circuit, the strength of the current C depends. The electrical power supplied is CE, and of this the motor utilizes C*e.* The efficiency is *e/*E*.* It is easily seen, as was first shown by Jacobi, that the power developed by the motor (C*e*) is a maximum when *e* = ½E. But this condition of maximum power involves that half the energy supplied is wasted; to secure higher efficiency, motors are in practice run at much less than their maximum power, so that *e* may approach more nearly to equality with E. The field magnets of motors, like those of dynamos, may be wound with coils in series with the armature coil, or with coils forming a shunt to the armature, or with a combination of both. A very important part of the theory deals with the automatic regulation of speed by the use of compound winding. In a paper of funda­mental importance with regard to this part of the subject, Messrs Ayrton and Perry@@3 have shown that a motor may be made to run

@@@1 For a comparison of the weights to be drawn and the tractive force required in different systems, see a paper by Mr Reckenzaun, *Elect. Rev.,* May 21, 1886.

@@@2 For details of the construction and working expenses of these and other lines, see the valuable paper by Mr Reckenzaun, *Jour. Soc. of Arts,* April 20,1887. Statistics of American lines will be found in a paper by T. C. Martin, read before the American Institute of Electrical Engineers, May 18, 1887.

@@@3 “ Electromotors and their Government,” *Jour. Soc. Tel. Eng.,* 1883.