into extended commercial use. Single-phase motors for a given power are much larger, heavier and more expensive than the ordinary direct current motors, owing to the low magnetic densities at which the iron is worked. The power factor is between 0∙75 and 0∙85.

The advantages of the single-phase alternating system lie in the fact that it combines the simplicity of the overhead direct current con- struction with the possibility of exceedingly high voltage. Where heavy traffic is to be handled, and especially where that traffic is scattered, a direct current system, which up to the present has been limited in its voltage, is not commercially possible, as the amount of copper used for distribution and the excessive amount of apparatus required to convert high tension alternating current into low tension direct current, would make the cost prohibitive. In direct current

systems for lines of any length, it is the custom to use alternating current of high potential and to reduce it to direct current of low potential at different points along the line. This involves rotary converters, which by their nature require attendance in the substations. while if the traffic is scattered so that the load on the substations

may at times be zero, and at other times may be very large, the capacity of the sub-stations must be equal to handling a maxi­mum load, so that the total capacity of each sub-station would be based on the maximum instead of on an average condition. With the single-phase alternating current system, on the contrary, only static transformers in sub-stations along the line are required, and with the high voltages available (voltages as high as 11,000 volts are used at present) the distances between these sub-stations can be greatly increased as compared with the direct current sub-stations, so that each sub-station feeding a much longer portion of the line would have a better average load than in the direct current case. The static transformers do not require attendance, and their efficiency is much higher than that of the rotary converters.

Electric motors for traction purposes have been highly elaborated and developed. At first they drove the car axles through belts or sprocket chains, the motor being sometimes attached to the car, sometimes to the truck. At Richmond, however, in 1887, the Sprague method of communicating the power from the motor axle to the car axle was put into practical operation, and this has with slight modifications been retained. It consists of sleeving one end of the motor on the ax!e, suspending the other

flexibly from the car body or truck, and driving from the armature through spur gearing. At first the motors were too small for the work demanded of them. Their high speed required a double reduction in gearing, their overheating caused continual burn-outs, and the sparking at the commutators necessitated constant repairs. These defects were gradually eliminated. The motors were made larger, the quality of the iron and insulation was greatly improved, and finally a four-pole motor requiring only a single-speed reduction by spur-gearing was produced. Since that time further improve­ments in material and design have been introduced, and the present motor has been evolved. Almost all the standard modem traction motors are of the same general design. , They are series wound, *i.e.* the same current passes through both the armature and the fields. This gives a strong starting torque or tractive effort, the torque diminishing as the speed increases. This characteristic is particularly suitable for. traction. Fig. 9 shows the relation between speed and tractive effort of a standard railway motor of large size and power. The armature is built up of carefully tested iron disks, which are deeply slotted to make room for the coils. These are wound and insulated separately, and placed in the slots in the armature core; sometimes they are held in place by binding wire, sometimes by wedges. The commutator is put in place, the coil connexions soldered to it, and the proper end-coverings put on. The magnet frame is made in two parts, of cast steel, enclosing the entire armature. A lid in the top casting gives access to the brushes, which are of carbon. the field coils are wound on forms and properly insulated. When in operation it is practically water