regards ability to bring up other apparatus for clearing the track. In fact, if the presence of a third, and probably a fourth rail were a necessity in connection with the introduction of electric traction, it is seriously to be doubted whether most of our railway companies would ever be brought to consider it. Other serious drawbacks, such as the comparatively large rheostatic losses occurring at the starting up of motors, also the dangers from electrolysis, might be mentioned showing the unsuitableness of this system for heavy traction.

2. Alternating direct current. In this method of distribution, the losses in transmission and the expenditure for copper are avoided by distributing alternating current at a high voltage to sub-stations placed at convenient distances, in which are installed step-down transformers and rotary converters which convert the alternating current of lowered pressures to 600 volts direct current feeding it into trolley of third rail. This is the system adopted by the New York Central Rd., and is the one installed by the Lancashire and Yorkshire Ry. on its double tracked 23 mile line between Liverpool and Southport. Alternating current three phase power is generated for this road at 7,500 volts, of a frequency of 25 cycles, and is transmitted from a power house to four sub-stations, which step-down the high tension current to low tension alternating current, from which it is converted in rotary converters to direct current, at 600 volts. This power is fed thence through feeder conductors, to the third rail, and returned from fourth rail, bonded to each running rail by return feeders. The drawbacks to the previous system apply equally to the direct current part of this system, and in addition there are the disadvantages of the sub-stations containing the direct current rotary converters, which being revolving machines require manual attendance, entailing a large initial expenditure, and a large operating staff as well as increasing liability to break down, by the introduction of another link in the electric circuit. In view of the various disadvantages, as mentioned in the foregoing, it might be interesting to look into the reasons for the adoption by the New York Central Rd. of this system. The reason for their action, it would appear, were those of policy, as well as engineering. The word policy in this respect refers to the idea that the system adopted should leave every opportunity for the possible future interchange of equipment with other local systems, including the rapid transit lines. The relative costs of the a.c. and d.c. systems were in favor of the direct current equipment, and a further objection to the a.c. system was the use of an overhead construction of bare wire in tunnels and viaducts, which included liability of injury to trainmen as well as a tendency to corrosion of wires from the gases of freight steam locomotives. Among other points, was the fact that the a.c. locomotive would have a greater weight, thus adding 7 to 10% to the train weight, with a consequent increased cost of transmission, installation, and operation of power plants. Further, the cost of maintenance of alternating current apparatus would be greater. The depreciation would also be greater, due to the equipment being more novel, and more or less untried, and would, therefore, have to be discarded in the near future to make room for improved types, whereas the direct current apparatus, being standardized, and universally in application, would prove a good asset.

3. The single phase system to-day is, in the opinion of the majority of engineers, the one which is essential for heavy and long distance railway service, and conforms to the ideal requirements for electric traction. The development of the system has only become prominent and made possible within the last two years, due to the fundamental feature of the system, the single phase commutator motor having been brought to a high degree of perfection for railway work. It should be borne in mind that the advantages accruing from this system, are due primarily to the use of alternating current, rather than to any advantages, of the a.c. railway motor over the d.c. railway motor, though it should be noted that it has equally good characteristics, and is almost as efficient. The credit of the many advantages gained with this system, however, must be given to the a.c. railway motor since its development has made the exclusive use of single phase alternating current on railway systems practicable,

The details of one of the several single phase roads now operating are as follows: Power is generated at 2,200 volts, and in the power house, by means of static transformers having no moving parts, transformed to 33,000 volts. At this voltage, it is transmitted to transformer stations, located every 10 or 12 miles along the line, where it is reduced to 3,300 volts and fed to the trolley. The transformer stations require no attendants, as the feeder lines are all controlled from the power house, and the stations have no apparatus with moving parts. The 3,300 volt trolley current is carried into the car by a bow trolley, and through a static transformer, in the car, reduced to 250 volts for which the motors are designed. This is an extremely flexible system; by making changes in the transformers, which are not expensive and always good assets, the transmission voltage or the trolley voltage can at any time be changed to meet the requirements of new conditions which may arise. The trolley voltage could be increased to 6,000 volts, which would give sufficient power for operating 100-ton locomotives, with the same size trolley wire, in use. In order to protect passengers and crew from the high pressure used in this system, all car wiring is placed in metal conduits and connected to trucks, so that should any defect in insulation develop it will result in the tripping of the automatic circuit breaker in car or locomotive.

With the single phase a.c. system, the overhead conductor and its many advantages are retained. There are objectionable features to its use, some of which may be named as follows: Difficulty of securing head room through tunnels under bridges as existing structures. These have been eliminated by using a third rail. Snow and ice will collect on the trolley wire. This has been overcome, with more or less success, by coating wire with various solutions or greasing it, by supporting wire from underneath, and collecting current from top of wire, as is done in several Swiss installations, or by passing a heavy low voltage current through wire, raising temperature of same. Poles and guy wires breaking, and allowing the trolley wire to fall, or breakage of trolley wires. These latter objections are possible to avoid by better construction, which has been introduced with the single phase railway, and consists of a catenary suspension cable or cables supported on insulators on suitable brackets from poles, trolley wire being suspended at intervals of ten to twelve feet from steel cables; this method of suspension allowing of trolley wire being kept at a uniform height above the tracks. For heavier service steel bridges spanning tracks, and carrying the suspension cables, may be used. Liability of a break occurring is reduced to a minimum by using two cables.

A summary of the principal advantages of the a.c. electric traction over the d.c. are: Limits to trolley voltage are removed. Avoiding of rheostatic losses. No necessity for rotary converter sub-stations with manual attendance. Danger of electrolysis by return current avoided. These and other advantages are so well recognized by engineers, that this form of electric traction is now being taken up in England, Europe, and South Africa, as well as on this continent. The Swedish Government Railways have purchased equipment, and are making experiments with trolley voltages up to 18,000 volts, and eliminating the use of sub-stations with step-down transformers for lowering transmission voltage to a lower trolley voltage. In South Africa the Government has recently placed an order for the equipment of one of its main lines with this system.

In order to consider more in detail the relative costs of the alternating and direct current systems I give herewith a comparative list of costs of entering into the equipment of a 60 mile interurban road where the schedule proposed requires five local cars having one hour headway; one express car making the round trip in three hours and one freight car making trip between terminals in eight hours.

POWER-HOUSE.	Direct-Current.	Alternating Current.
Building	$10,000	$10,000
Foundations	2,500	2,500
Boilers and settings	12,000	12,000
Steam piping and covering	7,500	7,500
Engines	22,000	22,000
Generators	18,000	23,000
Exciters	1,000	1,000
Step-up transformers, 800-kw	8,000	7,500
Switchboard	3,500	3,000
Wiring	3,000	2,500
Feed-water heater	800	800
Pumps	800	800
Coal storage	1,000	1,000
Smoke-stack and flues	2,000	2,000
Fuel economizers	3,000	3,000
Stokers	3,500	3,500
Incidentals	4,400	4,400
Totals	$103,000	$106,500
SUB-STATION IN POWER HOUSE.		
Building extensions	$1,000	$1,600
Synchronous converter, 300-kw.	4,800	
Transformer, 300-kw.; 200-kw. alternating current	3,200	2,000
Switchboard	2,000	1,300
Wiring	1,000	500
Incidentals	600	200
Totals	$12,600	$4,600