grade at 20 miles an hour. This does not necessarily mean that the electric locomotive unit will be four times as powerful as the steam unit. It can be. It is more probable, however, that the electric unit will be a 1,500 h.p. or 2,000 h.p. engine, and that these units will be articulated to give the required power. The articulated units will be controlled as one unit from one master controller.

Speaking of London, Eng., terminal conditions, Mr. Dawson says: "The use of electricity, taking into consideration the small proportion of long distance trains to local ones, will practically result in doubling, not only the average speed of local trains, but also in doubling the carrying capacity of existing lines and terminals." Mr. Sprague, speaking of American city terminal conditions, says: "As a net result it may be safely stated that so far as the train movements are concerned, the capacity of the yards, over and above that required for the storage of cars alone, can be trebled as compared with steam locomotive-drawn trains. In addition (smoke being eliminated) the yards can be roofed over and the space (overhead) utilized for streets, parks, and buildings."

Admitting that electrification is a cheaper alternative than laying new tracks on grades, building new tunnels, and enlarging terminals, it is not the only alternative so far as main line work is concerned. The addition of a block signal system on the miles of line not yet so equipped will increase the capacity of the railway system, and will do it much cheaper of course than electrification can do it. W. N. Smith points out that while double tracking increases the capacity fourfold, there is plenty of room for increasing the capacity of existing roads by equipping single track roads with block signals, since but 17% of the single track roads in the U.S. are protected with block signals, and single track roads constitute 70% of the total mileage. He admits, of course, that electrification will increase the capacity of roads already equipped with block signals.

Notwithstanding the fact that electrification increases capacity, reduces operating expenses, and improves service, in general the existing electrifications have been forced on the railways. In some cases, tunnels for instance, it has been brought about by legislation. In other instances, such as subways and terminals, the smoke nuisance has forced the issue. So far as suburban lines are concerned, street car competition has been the agent. The West Jersey & Sea Shore Rd. is, perhaps, the most conspicuous instance of voluntary electrification.

Even granting that one electric locomotive can do the work of two steam locomotives, and that the maintenance of the electric locomotive is half that of the steam, it does not follow that a general electrification of the American railway system would result in an electric locomotive doing as much for a dollar as the steam locomotive does for two. The functions of a locomotive in an industrial community, like that of America, is to pay dividends, but it cannot pay dividends until it has paid the operating expenses and the fixed charges of the railway system. If there is anything left of the revenues after paying the operating expenses (maintenance of way and structures, maintenance of equipment, conducting transportations, and general expense), and paying the fixed charges (interest on funded debt, interest on floating debt, rentals, taxes, and sinking fund), why, the remainder (the net earnings) is applicable to dividends. Now, according to the estimate of Messrs. Stillwell and Putnam, if all the U.S. railways were operated by electric power instead of steam, the aggregate cost of operation which in 1905 was $1,400,000,000.00, would have been $1,150,000,000.00. That is to say, the cost of electric operation would have been 82% of the cost of steam operation. This saving of $250,000,000.00 (18% of cost of steam operation) would not only have paid the fixed charges on the electric investment, but would have increased the net earnings. The conclusion then is that the ratio of the operating expenses and fixed charges of an electric system to the operating expenses and fixed charges of an equivalent steam service is nearer 1 to 1 than 1 to 2. The discussion is academic. Such a thing as the possibility of a general electrification is not even intimated. The general conclusion, however, is irresistible—electrification is the means of increasing the capacity of a congested railroad division.

ELECTRIFICATION—WHERE IT IS BEING DONE.

Admitting for the sake of argument that electrification will increase capacity, improve service, and reduce operating expenses, concrete instances of electrification justify these conclusions. Take the case of the Mersey Ry., a short main line road connecting Liverpool with Birkenhead, Eng. It is a tunnel road. It was electrified to eliminate smoke and meet ferry competition. The traffic is almost exclusively passenger. The system is direct current third rail 650 volt with multiple unit trains. The electric service was substituted for the steam service May, 1903. Mr. Dawson points out that a comparison of the electric service with the steam shows that the train mileage in 1901 (steam) was 311,000 miles, while in 1906 (electric) the train mileage was 829,000 miles. The locomotive charges per train mile in 1901 (steam) were 13.65 pence (approximately 27.7c.), while in 1906 the locomotive charges per train mile were 5.95 pence (approximately 11.9c.). The locomotive charges include power, locomotive wages, locomotive maintenance and repairs, and office expense. This increase in train mileage was effected by the increased schedule speed and the increased train frequency. This livening of the service enabled the weight of the train to be cut down to about one-half that of the steam trains. As a net result, this augmentation in service has been effected with an increase of 10% in the total operating expense. The smoke, of course, has been eliminated and the traffic is increasing.

The Mersey is not the only instance in England of the application of direct current third rail system to a steam road. The Great Eastern Ry. has electrified the line between Newcastle and Tynemouth. The Lancashire and Yorkshire has electrified the line between Liverpool and Southport. The District Ry. in London has been completely electrified. The Metropolitan (underground) has electrified all of its London lines. The direct current third rail system is used in each instance. In the case of the Great Eastern the change was made to meet tramway competition. The cost per locomotive mile has fallen from 14.5 pence (steam) to 6.75 pence (electric). The L. & Y. electrification was necessitated by tramway competition. The accelerated service resulting from electrification has had the desired effect. The District and the Metropolitan were electrified to augment their revenues by increasing the capacity of the system and improving the service. The increase in capacity and the improvement in the service have been realized, but the physical conditions are so extraordinary that a marked increase in the net earnings is not as yet being realized. However, confidence in the ultimate result is manifested by the work of consolidation, and extensions of electrifications that these lines are carrying out.

The third rail direct current system is in use on the continent of Europe, but is mainly confined to subway lines such as the Metropolitan of Paris, and the elevated roads like the Berlin Overhead. The third rail line between Milan Galarate and Porto Ceresio, in Italy, is the most important installation of this kind in Europe.

The third rail direct current system is extensively used in America. It is in use on the elevated roads such as those in Boston, New York, Philadelphia, and Chicago. It is in use on more than 40,000 miles of light railways (interurban service). It is doing heavy railway work on the Lackawanna & Wyoming Valley Rd., connecting Scranton and Wilkes Barre, Penn.; on 97½ miles of the Long Island Rd.; on the West Shore Rd. between Utica and Syracuse, N.Y.; on the West Jersey and Sea Shore Rd., connecting Camden and Atlantic City,—65 miles, double track; and on the New York Central (electric zone). There are other instances, but these are representative.

The most conspicuous example of the application of the third rail system to heavy railway work is the New York Central electrification. Its electrical equipment consists of 35 electric locomotives, 131 motor cars and 55 trailers. The service was inaugurated Dec., 1906. The locomotives are equipped with 600 volt motors. The nominal capacity of the locomotive is 2,200 h.p., the maximum capacity, 3,000 h.p. Vice-President Wilgus, who had charge of the electrification, said recently that the maintenance of the electric locomotives is so much less than that of the steam locomotives, and that the amount of the time spent in the shops by the electric locomotives is so much less than that spent in the shops by the steam locomotives, that the saving neutralizes the interest charge and the depreciation charge of the additional investment; and, moreover, shows a net saving in repairs and fixed charges over steam equipment of 19%. Mr. Wilgus stated further that a comparison of the light repairs and inspection of the electric locomotive with the coaling, watering, drawing fires, repairs, etc., of the steam locomotives shows a saving in time in favor of the electric locomotive of over four hours a day—a saving equal to 18%. He says the electric locomotive is a more nimble and a more efficient machine than the steam locomotive—that it has increased the daily ton mileage 25%. He added that the increased current consumption per ton mile for high speed service is 18%, while a corresponding increase in speed with steam service would run up the coal consumption 165% a ton mile.

The third rail direct current system is not as applicable to long distance heavy railway work as it is to the short haul. The low voltage of the direct current motor seriously handicaps the application of this system to heavy long haul work. The normal pressure of the direct current railway motor is 600 volts. This means heavy currents for heavy power. Heavy currents mean a third rail since the overhead trolley cannot handle heavy current. The third rail, of course, is not a desirable adjunct to the permanent way. Now heavy current cannot be transmitted economically more than a few thousand feet. This means that there must be substations at frequent intervals along the line. These substations draw high voltage alternating current from the transmission line and deliver low voltage direct current to the third rail. The change from alternating current to direct means moving machinery. Moving machinery requires attendants. Consequently the application of the low voltage direct current to long distance heavy railway work is handicapped by the physical objection to the third rail and the financial objection of the expense due to substation and feeder investment and the expense of substation crews. The advent of the 1,200 volt direct current railway motor will diminish the number of substations, but even with this voltage the current required for heavy freight service will be too heavy for the overhead trolley. The third rail cannot be insulated to stand this voltage. Conse-