regions, and the leaching of the salts and the underlying rocks is small, the removal of soluble matter has not gone on to such a degree. Immediately below the surface there are evidences of their presence, and in localities of very small rainfall and very scanty drainage, and where the evaporation of the soil moisture has been excessive, the salts often appear as an efflorescence on the surface of the ground. The source of alkali salts at Billings is in the shale forming the bluffs on the south side of the valley, rather than in the sandstone of the north bluff, which is shown in our engraving.

The Yellowstone River at Billings traverses a broad valley from six to ten miles wide. The valley is bounded on either side by high bluffs. On the north side the bluff is of sandstone and on the south side steep, ragged hills of blue shale. The sandstone is a gray, siliceous stone, rising abruptly to a height of from 200 to 500 feet above the general level of the valley. Small, but perceptible quantities of magnesium and sodium sulphates are to be found throughout the sandstone rocks and where evaporation has gone on from the surface for a considerable time, while crusts of these salts form on the surface. Water seems to percolate through fine veins and cracks in the rocks and issues at the sides and the foot of the bluffs, in many places giving rise to springs of alkali water containing a greater or less amount of soluble sulphates. The main body of sandstone has been eroded rather unevenly and the peculiar pinnacle-shaped structure is seen that is so characteristic of the "Bad Lands." The face of the bluff is completely rounded by weathering, and the general ragged character is smoothed off by the continual falling of the debris due to the rapid disintegration of the rock freely exposed to the weathering influences. Underlying the sandstone and coming out from under the bluff, there is a fine blue shale or slate which extends to an unknown depth. The shale rises up from beneath the sandstone and forms the rough angular blue hills on the south side of the valley. The shale is penetrated with numerous fine cracks and joints run-

determined. This will give the resistance of an amount of soil solution equal to that in the cell and without the presence of the soil. The specific resistance of this solution can then be determined, and by comparing this with the specific resistance of solution of different strength of sodium chloride or of any other salt, the actual amount of salt can be determined in terms of the salt used as a basis for comparison. Our engraving shows a complete outfit for the determination of the soluble salt content of the soils, as actually used in the field. The sample is taken out with an auger, mixed in the field in a porcelain dish, with distilled water, filled into a hard rubber cell and the resistance is then taken. The temperature of the cell is also taken. The calculation can be made on the spot or at any subsequent time. If the amount of moisture added is once actually determined, the variations in the amount added in different experiments have very little value. The moisture determinations do not, therefore, have to be made in each case. The method is extremely sensitive and is very rapid. The determinations can be made by one man quite as fast as the samples can be drawn by another, and much faster if the ground is hard and dry.

In carrying out the investigations three lines of borings were run; one of five miles in length and the others, for more detailed study, of about $1\frac{1}{2}$ and $1\frac{1}{4}$ miles respectively in length. The longer section began above the ditch and went down toward the river; the others extended from an alkali flat and from a drainage ditch back into the higher levels. These borings were all numbered and their position accurately marked on the working maps. In addition to this, a section or square mile of land was studied in great detail and borings were made at frequent intervals to a depth of 10 or 15 feet. A number of special borings were also made to study the relation of the different types of soil to the amount and distribution of the salts.

The results of the investigations have been illustrated by graphic diagrams in the Bulletin to which we have

ELECTRIC TRACTION AND ITS APPLICATION TO SUBURBAN AND METROPOLITAN RAILWAYS.*

By PHILIP DAWSON.

THERE is no longer room for doubt that electricity is the one pre-eminently successful motive power for tramways. This is proved by the rapid growth of electric traction. The words "experimental line" have fallen out of use, yet it is only a few years ago that those who ventured to foretell that the trolley system would be generally introduced into this country were ridiculed. There is no country in which electric traction is advancing more rapidly, and in which finer plants are being installed than in Great Britain. The day is not far off when horses and steam will have disappeared from the streets as far as tramways are concerned, and when the horse 'bus as a competitor will be no longer known.

The problem of greatest importance, however, in which electric traction will be a principal factor, is the rapid transportation of large crowds from and to their business in our cities. The object of this paper is to investigate in a general way the special requirements of this service and to demonstrate the special adaptability of electric traction to it.

It is evident that the only solution of rapid transit lies in railways which must be either overhead or underground, and of both London possesses a greater mileage than any other town in the world. The factor of initial expenditure must restrict the number of tracks available for the up and down traffic.

The stopping places on such lines must of necessity not be far apart, and to diminish the crowds on the platforms and to increase the number of passengers the trains must follow each other with the greatest possible frequency. Consequently the average speed of the trains must be increased as much as possible without unduly diminishing the distance between two consecutive trains, which would be dangerous.

Steam locomotives have probably reached their ap-

ONE OF THE IMPORTANT INDUSTRIES OF THE YELLOWSTONE VALLEY—FEEDING OF SHEEP AND RANGE CATTLE DURING THE WINTER SEASON.

ning in all directions, and these are filled with gypsum and calcium carbonate. The weathering of these two rocks, the sandstone and the shale, has given rise to the soils of the valley and they are themselves the present source of soluble salts in the valley; as the rocks weather, a portion of the soluble salts is removed in the springs and seepage waters, but the removal is not nearly so complete as is the case in the humid portion of the United States, because the small rainfall renders the escape of all of the excessive amount of salt impossible. These two types of rock give rise to two distinct types of soil in the valley—the first is a sandy soil, derived from the disintegration of sandstone rock, giving a soil of open texture, easily worked, in which there is less trouble from alkali on account of more perfect drainage and less risk of accumulation of seepage waters; the other type is a stiff clay or "gumbo" formed from the disintegration of the shale. The shale soils are extremely fertile when in good condition, but are quite difficult to work. They are easily puddled and are rendered almost impervious to water by the excess of soluble salts which they usually contain, and it is upon these soils with their poor underdrainage that the greatest amount of trouble has arisen from the accumulation of seepage waters and salts in the over-irrigation of the soils in the valley.

The method used by the Department of Agriculture in determining the soluble salt content of the soils in the valley is interesting. Briefly, the method consists in taking a sample of soil with an auger at any desired depth in the field, adding sufficiently distilled water to thoroughly saturate it, bringing it into the consistency of a thick paste. This is then filled into a hard rubber cell with electrodes, and the electrical resistance of the saturated soil can be taken as the resistance of a salt solution filled with inert grains of soil. The effect of the soil grains is to increase the resistance about 100 per cent. This effect is constant for all ordinary soils. The resistance of the soil moisture can be calculated by multiplying the resistance of the cell by this factor and reducing for temperature, which has previously been

referred. The investigations point clearly to the natural methods of preventing this injury by over-irrigation and of reclaiming the lands when once the injury has occurred.

The logical method of reclaiming consists in providing an adequate system of drainage to carry off the excess of water and the accumulation of soils. This is expensive, but is the only thing in this case to hasten the slow process of nature, which is entirely inadequate in the presence of the present methods of irrigation and of culture. Under-drainage is expensive, but it has amply repaid for the investment in other localities where the land is worth no more than in the Yellowstone Valley. The report is valuable as showing what care the government exercises over the farmer of the United States. All the resources known to modern science are placed at his disposal, and the greatest specialists in the world in their respective lines are constantly ready to come to his aid. The wise and liberal policy of the government as exemplified by the Department of Agriculture might well be emulated by other countries.

The subject of coal consumption in steam turbines is interesting, and entitled to some attention. Recent figures show that the new engines will consume 15 per cent. less coal than ordinary engines traveling at the same speed; and as the vessels and the engines increase in size, so does this difference increase—that is, the higher the tonnage, the greater is the superiority of the turbine to the ordinary engine in this respect. This, of course, means that less coal need be carried than for the ordinary engine for the same rate of speed; but it must not be forgotten that every knot which is added to the speed means, for any description of engine, a larger proportional increase in coal consumption the faster the boat is driven, and, although the turbine engine will consume less than the ordinary engine, the amount of coal required to sustain a speed of 35 knots is prohibitive of long journeys so far as small vessels are concerned.

proximate maximum development, and the results so far obtained with them for the class of traffic in question are far from satisfactory. They do not get up speed rapidly, owing chiefly to the torque on the driving axles constantly varying in consequence of the reciprocating motion of the pistons. They are not economical, as their fuel consumption is practically the same whether they are exerting their fullest power, coasting, or standing still, and their maintenance is very costly.

There is a commercial limit as far as distance is concerned beyond which transmitting power electrically will not pay. But that limit varies with each case, and cannot be ascertained except by the most careful calculation after all the conditions that obtain have been minutely examined. England was the first country to introduce electric traction on railways, both underground and overhead, as instanced by the City and South London, and Liverpool overhead electric railways. But, to prove commercially that very much heavier traffic could be handled, that much greater distances could be traversed, and to develop on a large scale the necessary machinery was again left to America, and hence the necessity of being practically confined to American experience and examples in this paper.

There are practically three methods of handling electrically the traffic on a railway, namely:

1. By locomotives or motor cars hauling a train of trailer cars.
2. By independent motor cars.
3. By a set of independent motor cars formed into a train and handled from the front car or from a so-called controller car. Each car, however, can be separated from the train, and it then becomes an independent motor car.

As regards the supply of the necessary current for the motors, there are three distinct methods:

First. By accumulators or storage batteries, which

* Lecture delivered before the Society of Arts and published in The Journal of the Society.

may be carried either on the motor car or locomotive, or on a tender.

Secondly. By having a car containing a stationary engine, dynamo, and boiler, which supplies the necessary current to the motors on the cars comprising the train of which it is part, and as proposed by W. Heilmann.

Thirdly. By continuous or multiphase current supplied directly from a generating station or from a sub-station which, in its turn, gets its supply of energy from the main station, the current being distributed either in the form of direct or polyphase to conductors running along the lines, and from which the power is supplied through sliding contacts on the cars to the motors.

The two former methods, as far as this paper is concerned, will not be discussed, as sufficient data are not available to justify their being considered.

The system of transmission of energy to the motors by means of conductors laid along the track will therefore alone be considered.

This method allows of several variations as far as the generation and distribution of power is concerned, among which the chief may be set down as follows:

(a) One continuous current generating station supplying current direct to contact rail. Where drop in pressure owing to distance becomes excessive, a negative "booster" may be used; it serves, so to speak, to pump back the current to the station, and is self-regulating, not taking at any period more power than is actually required to pump the current back. Should there be one or two lines too long to enable them to be worked this way, polyphase high tension generators should supply the power to one or more sub-stations along the line, as may be found necessary, in which rotary converters are located, which transform the current back into continuous. The polyphase generators to be driven by continuous current motors in the generating station. As an example of such a station, the new Dublin tramway power house may be taken.

(b) One central station generating continuous current with sub-stations in which accumulators are located along the road, and which are charged by means of a booster and special cables. As an example of this system, the Leeds tramways may be taken as designed by, and carried out by, the late lamented Dr. John Hopkinson.

(c) A series of stations, as described under (a) and (b), situated at various distances and connected together one with the other. As an example of this, the tramways and light railways in and round Boston, Mass., may be taken, owned by the Boston Elevated Railway Company, which has absorbed the well known West End Company.

DATA OF BOSTON ELEVATED RAILWAY.

Track miles operated.....	305
Number of cars.....	2,648
Car miles run during 1898.....	29,787,000
Passengers carried during 1898.....	172,764,300
Number of power stations.....	5
Total capacity of power stations in kilowatts.....	16,100
Total rated indicated horse power of engines.....	24,000

(d) A power station generating polyphase currents, which, by means of static step-up transformers, are transmitted at tensions which run from 2,500 to 40,000 volts to sub-stations where static step-down transformers reduce them to pressures of 300 to 350 volts; the current at this pressure enters rotary transformers, which deliver direct current at 500 to 550 volts to the line. As an example of this later system, the Central London Railway, which is now under construction, may be mentioned.

(e) A three-wire system with continuous current, the rails or return forming the neutral wire. This has been tried and found wanting, and the engineers of the Central London Railway most carefully investigated its possibility and decided in favor of polyphase transmission and rotary converters, and rightly so.

From careful calculations and the investigation of what has been done both in Europe and America, there is no getting behind the fact that for any power station which will exceed 4,000 kilowatts in capacity, the polyphase system is nearly certain to prove commercially the only admissible one. This statement is upheld by such an authority as Mr. H. F. Parshall, M.I.C.E. It is evident that in the particular cases at present under consideration (suburban and metropolitan communication), more than 4,000 kilowatts will be under consideration, and, therefore, nothing, as far as the power station and transmission is concerned, but polyphase currents will be considered.

There are two distinct varieties of service to be catered for. One that on a system like the Metropolitan and District, where the stops are frequent and the runs short. The other the case of long distance lines with few stops. In the present paper it is only proposed to consider the first variety. In this case the use of polyphase motors need not be considered, as, for work entailing frequent stopping and starting, they have not up to date proved satisfactory.

A short examination of the importance of rapid acceleration on lines having stopping places at short intervals is interesting. Practical experience with electrically driven motor cars or locomotives on the experimental track of the General Electric Company, at Schenectady, has proved that it is perfectly feasible to attain a speed of 30 miles an hour 10 seconds after starting from a standstill. Assuming a level track, and that during 65 seconds the current is cut off and the train allowed to coast, that the brakes are then put on, the train will be brought to a standstill 15 seconds later, and the total time from start to stop will be 90 seconds. Under these conditions it will be found that the average speed will have been 23.16 miles an hour, and that the total distance run will be about 0.55 of a mile. Assuming that instead of attaining the 30 miles an hour in 10 seconds, it took 30 seconds, and that this full speed of 30 miles an hour was kept up for 40 seconds longer, and the brakes then put on, the train would be brought to a standstill in 90 seconds, and the average speed would work out as 21.66 miles an hour, or an average speed of about 10 per cent. less than in the previous case, the consumption of power, however, being much greater.

It is evident that the most important point is to

attain a high average speed, and to keep the maximum speed attained as low as possible, as by so doing less power is required in braking the train, and also less power is required to run the train. The time between the moment when the maximum speed is attained and when the brakes are put on should be at least from 4 to 6 times that required for stopping the train, so as to allow for errors in judgment on the part of the driver, and also to enable him to make up lost time. On the Manhattan Elevated Railway, in New York, the trains, which are drawn by steam locomotives, take 20 seconds to attain a speed of 14 miles an hour, or less than half the speed in double the time as compared with electric traction just mentioned.

A much larger current will be required to attain a rapid acceleration than to attain a slow one, but the current will be required during a much shorter time, and the total energy supplied will be less in the case of rapid than of slow acceleration. This fact must not be lost sight of when calculating the feeders for such a system, and the train service should be arranged in such a way that as few trains as possible start together. Furthermore, the more rapid the acceleration required, the larger will the motors have to be, and, therefore, there will be a limit, above which it will not be advantageous to push the rapidity of acceleration. In new tunnel lines, such as are now being constructed all over London, it will be evident that it is an advantage to have the stations built with a down grade for the trains to start, so as to help the motors and reduce the current required at starting, and that similarly it will be an advantage to have an up grade when nearing a station, so as to reduce the amount of power required in braking. By properly choosing these gradients, it is found that a total economy of from 40 to 50 per cent. in the total power required by a train may be made. According to Mr. Potter's tests, it was found that during acceleration an average power of 32 amperes per ton of weight of train was required.

With a complete train composed of one motor car and two passenger cars, weighing complete 148,000 pounds, a maximum horizontal effort of 9,750 pounds was required in acceleration, the maximum current was 780 amperes at 500 volts, the maximum speed attained was 32 miles an hour, and the time taken to attain the speed was 34 seconds, the motor car being equipped with two 200 horse power motors.

METROPOLITAN ELEVATED, CHICAGO.

Number of Cars in Train.	Average Speed (not including stops) in Miles per hour.	Average Current (not including stops) in Amperes.	Board of Trade Units Delivered at Switchboard per Ton Mile.
4	14.4	148.7	.050
4	14	153.2	.053
4	14.5	151.8	.050
3	14.7	137.4	.063
3	15.1	135.6	.058
2	15.3	90.1	.058
2	16.8	106.6	.059
4	12.2	101.1	.042

Railway Co.	No. of Cars.	Weight of trains in lbs.	Tractive effort per ton.		Maximum speed in miles per hour.	Distance run.
			Maximum for given time.	Average for total time.		
Metropolitan Elevated, Chicago	2	88,000	10 177	40 107	34.8	1,020
Lake Street Elevated, Chicago	2	88,000	10 135	40 84	27.6	870
Alley Elevated, Chicago	3	144,000	10 135	40 98	28.6	840
Illinois Central, Chicago	4	300,000	10 95	40 79	25.60	750
Manhattan Elevated, New York.	4	190,000	10 88	40 67	21.00	615

In another case, with a train composed of one motor car, equipped with two 125 horse power motors and one trailer car, the total weight of train being 103,000 pounds, a maximum speed of 31 miles an hour was attained in 37 seconds, the maximum current being 500 amperes and the maximum horizontal effort required to attain acceleration 5,640 pounds. In a series of tests made on the Nantasket Beach line it was found that with a heavy motor car, 51 feet in length over all, carrying 100 passengers, weighing 21 tons, on an average distance of 2,980 feet between stations, a maximum speed of 40 miles an hour was attained, the average speed being 18 miles per hour, and the power required was 0.098 Board of Trade unit per ton mile.

In an experiment with a train composed of one motor car and one trailer car, weighing 57 tons, with an average distance between stations of 4,280 feet, a maximum speed of 37 miles was attained, the average speed being 17 miles an hour, the power required being 0.067 Board of Trade unit per ton mile.

From a comparison of the actual results obtained on the elevated electric railways of Chicago and on the Metropolitan and District line in London, we see that whereas the maximum speed of 25 miles an hour is obtained in 10 seconds with electric traction, it takes 33 seconds to do it with steam locomotives, and that while the electrically propelled train could do the distance of 1,880 feet in 66 seconds, with steam it would take 93 seconds, or nearly half as much time again. If in the case of electric traction the power is cut off the moment the maximum speed of 25 miles an hour is obtained, and the train allowed to coast before the brakes are put on, the distance considered would be done in 76 seconds. The steam-driven train even then would take more than 25 per cent. more time to do the same distance.

Having tried to show the advantages which electric traction possesses as regards the possibility of increas-

ing the frequency of the trains without decreasing the factor of safety, namely, the distance between two trains, it may be advantageous to see how, from an economical standpoint of generating power, electricity is a cheaper method of operation than steam locomotion. An electrically driven train only requires one man instead of two to drive it, and when the train is not running no power is consumed and no coal or water wasted. Steam locomotives, it is well known, use but very little less coal and water when they are standing still than when they are running, and are much less economical, consuming, as they do in America, from five to six pounds of coal per indicated horse power. On main line English roads it is stated that three to four pounds are consumed, and taking an average power of 400 horse power per locomotive, and a train plus engine weighing 250 tons, at a speed of 40 miles an hour, we get at the most economical rate about 0.65 pound of coal per ton mile, or, compared to the electric power required by electric traction, 13 pounds of coal per Board of Trade unit required, which is enormous; under favorable conditions it would not take much over 3 pounds of coal to give one Board of Trade unit at the switchboard. A properly designed electric station with large units would probably never consume more than 2 pounds of coal per indicated horse power hour, or 2.65 pounds per kilowatt hour at the switchboard, and engines of the size of 4,000 to 6,000 horse power would be guaranteed to consume not more than 12 pounds of steam per indicated horse power hour. A large station would fully justify a comparatively large initial expense in coal handling and stoking machinery, and the location of the station could be chosen so as to be most advantageously situated as regards both coal and water, the coal without being handled being taken from either the ship's hold or the railway truck, conveyed automatically to the coal stores, and from thence automatically to the fires, the ashes being conveyed away automatically as well. In such a station but very few men would be required, and the cost of power could be reduced below one halfpenny per Board of Trade unit, including expenses of every kind.

DISTANCE 2,000 FEET, TO BE RUN OVER IN 75 SECONDS, OR AT AN APPROXIMATE AVERAGE SPEED OF 16 MILES PER HOUR.

Time during which power applied in seconds.	Maximum speed attained in miles per hour.	Time during which brakes applied.	Average power-consumption, per ton, in B.T. units.
7.5	25.75	10.0	0.035
12.5	26.00	10.5	0.036
16.5	26.25	11.5	0.038
24.5	27.15	12.5	0.0475
31.0	28.25	14.0	0.0480
39.0	30.50	17.0	0.0575
53.0	36.50	22.0	0.0840

Distance to be run 2,000 feet.

Tractive effort per ton in lbs.	Maximum speed in miles per hour.	Time in seconds during which brakes applied.	Time in which 2,000 feet run.	Average speed in miles per hour.	Board of Trade units per ton mile.
300	62.5	41.0	41.0	33	0.300
150	53.0	34.0	52.0	26	0.196
100	46.0	26.0	58.0	23	0.160
65	40.0	24.5	67.5	20	0.130
45	34.0	22.0	82.0	17	0.100
35.6	27.5	15.0	98.0	13.4	0.075
27.6	23.0	12.0	127.0	10.4	0.057
	17.5	11.0	160.0	8	0.045

Comparing again the coal consumption per train mile on large English main line railways, which varies from 35 to 58 pounds of coal per train mile, we get a coal consumption of from 0.146 to 2.32 pounds per ton mile, corresponding to 28.12 to 46.4 pounds per Board of Trade unit, required to be generated at the power house. The following results actually obtained with slow speed Corliss type engines and standard American railway generators may be of interest:

Total coal consumed, Brooklyn City Railway Company, per Board of Trade unit, 3 pounds.

Total cost, everything included, of Board of Trade unit at switchboard, 0.5195 cent (about one farthing).

Cost of coal per unit, 0.2307 cent, about 0.166 of a penny; Union Traction Company, Philadelphia.

Poorest coal, 3½ pounds consumed, per Board of Trade unit at switchboard.

In another case cost of coal 0.272 cent per Board of Trade unit at switchboard, about 0.186 pence.

Total cost of unit, all included, 0.591 cent, about 0.296 pence.

Coal consumption in another case with Corliss engine, average for one year, per indicated horse power hour, 1.65 to 1.76 pounds.

What good slow speed Corliss engines, properly designed for railway work, compared to other engines mean is shown by the fact that by such a change in a large American station the coal consumption was reduced from an average of 8.3 to 4.9 pounds of coal per car mile.

From a series of figures obtained from the various Chicago electric overhead lines, from 0.16 to 0.135 Board of Trade unit is required at the switchboard to drive the trains, the average speed of the trains being 13½ miles an hour, and the maximum speed obtained varying from 28 to 35 miles an hour.

The coal and water consumption, per Board of Trade

unit, must necessarily be very low, the losses in the step-up and step-down transformers and in the transmission and rotary converters would not be very great, and it would be perfectly feasible to attain an efficiency of 60 per cent. at the motor terminals and of 50 per cent. on the power applied to the car axles. Large engines and large generators and converters are designed so as to take an overload of 25 per cent. for any period of time, and be capable of overloading 50 per cent. for a short time without injury, and by a selection of proper units a very large economy could be attained.

METROPOLITAN ELEVATED, CHICAGO.

Length of street. 36¼ miles.
Average distance between stations . . . 1,600 feet.
Time interval between consecutive trains 2½ minutes.
Average speed in miles per hour. . . . 13 miles.
Maximum speed. 28 "
Total rated power of generating station. 5,000 kilowatts.

SOUTH SIDE ELEVATED, CHICAGO.

Length of street. 18½ miles.
Average distance between stations . . . 1,720 feet.
Time interval between consecutive trains 1½ minutes.
Average speed in miles per hour. . . . 14 miles.
Maximum speed in miles per hour. . . . 26 "
Total rated power (4 units 800 kilowatts each) of generating station. . . 3,200 kilowatts.

LAKE STREET ELEVATED, CHICAGO.

Length of line. 15 miles.
Power of station 3,000 kilowatts.

NORTHWESTERN ELEVATED, CHICAGO.

Length of line. 15 miles.
Rated power of { 3-1,500 kilowatts. } 5,300 kilowatts.
station. { 1-800 " }

LOOP, CHICAGO.

Length 4 miles.
Rated capacity of { 4 units } 6,000 kilowatts.
station { 1,500 kilowatts. }
Number of trains passing over line in 24 hours. 3,000 trains.
Total rated power of Chicago elevated lines, approximately. 22,500 kilowatts.

NANTASKET BEACH.

Length of line. 20 miles.
Rated power of station. 1,800 kilowatts.
Average distance between stations . . . 4,280 feet.
Maximum speed per hour. 43 miles.
Average speed. 25
Board of Trade unit per ton mile, at switchboard 0.0808
Weight of two-car train 55 tons.

The elevated railroads of New York and Brooklyn have been losing business during the last few years so rapidly that the financial condition of the Brooklyn system is serious, and the return on investment of the New York system much reduced, and is still declining. The elevated railroads of Chicago have never been able to earn a satisfactory dividend. The general introduction of electricity in the Chicago system has greatly improved the Chicago situation, in spite of the competition of the surface trolley lines, which parallel the elevated lines in most cases. The elevated railroad problem is resolved into a discussion of speeds, station frequencies, and relative costs of service. Any railroad of this class which aims to maintain a high schedule must choose a motive power in which the possibilities of rapid acceleration are a maximum, and, all other conditions being equal, should choose that particular motive power which will bring about the quickest acceleration consistent with due economy.

The Manhattan system is a comparatively simple one, with four main through lines, without branches of importance, while the Brooklyn and Chicago systems are composed of trunk lines with branches, involving more or less complicated switching arrangements. Until about a year ago, the three Chicago companies, the Lake Street, the South Side and the Metropolitan, had independent termini in the business heart of the city. Now, however, the newly constructed "Loop," encircling the business district, is used as a terminus for all three lines and for a fourth, the Northwestern, now under construction, and all the elevated trains of the city pass round this loop on each trip. The Brooklyn elevated system has lately secured a new terminus on the Manhattan Island side of the Brooklyn Bridge, and experiments are being made with a view to converting the entire Brooklyn system to electricity in the near future. The entire New York system, however, is at present operated by steam locomotives.

The little locomotives in use on the New York system weigh 47,000 pounds, of which 31,500 are on the four 42-inch driving wheels and 15,500 are on the four 30-inch truck wheels. The total wheel base is 193 inches, of which 60 inches is rigid. The cylinders are 12 inches in diameter and have a 16-inch stroke. The grate area is 16.5 square feet, and the total heating surface is 4,034 square feet. There are 154 flues 1½ inches in diameter and 75 inches long.

The standard Manhattan car weighs 29,088 pounds, has seats for 48, and frequently carries 100 passengers. It is mounted on eight 30-inch wheels.

The total weight of a 5-car loaded Manhattan train is about 130 tons. The weight on the drivers is 12 per cent. of the total train weight, and with 25 per cent. adhesion, the maximum drawbar pull possible for the locomotive to exert is 7,875 pounds.

The electric locomotive car of the Metropolitan Elevated Railway Company, of Chicago, weighs 53,200 pounds complete with motors, or 40,000 pounds exclusive of motors. It is a standard American passenger car with full seating capacity, about one-half of each platform being taken up with the cab and necessary controlling apparatus. The trail cars weigh 33,000 pounds. The seating and standing capacity of both motor and trail cars is approximately 90 passengers. The average 4-car heavily loaded train will weigh about 100 tons, of which 32.5 tons approximately are on the four wheels of the locomotive's motor truck

and 67.5 tons are in the trail cars. From 30 to 35 per cent. of the entire train weight is available for traction under these conditions, and the maximum drawbar pull possible to exert without slipping of wheels is about 16,250 pounds.

The South Side Elevated Railway Company, of Chicago, is equipped with the Sprague multiple unit system, by means of which two or more cars in a train are equipped with motors and may be operated in unison by a single controller from any point in the train. The company is now operating 4-car trains on each of which is a motor truck carrying two motors. The cars weigh about 20 tons each without load, and about 60 per cent. of the train weight is available for traction.

easy to ascertain that this would greatly increase the average speed and therefore decrease the time necessary to do the distance.

The characteristic difference between the acceleration curve of a train hauled by a steam locomotive and one driven electrically is that, whereas the acceleration where steam is used as motive power increases at first, slowly following a curve which is nearly tangent to the horizontal or time axis, the acceleration curve in the case of electric propulsion is represented by a straight line rising very rapidly, and forming a very small angle with a vertical axis.

It may be interesting to mention a few details regarding the two large power stations which are now

American Rating.			H.P. Imputed.	Amperes (Full Load).		Full Load.	Commercial Efficiency.		
Poles.	kw.	Speed. Revs. per Minute.		500 Volts.	600 Volts.		75 % Load.	50 % Load.	25 % Load.
6	165	200	237	300	275	93½	93½	92½	89
6	225	200	321	410	375	94	93½	93	89½
6	225	150	321	410	375	94	93½	93	89½
6	225	120	321	410	375	94	93½	93	89½
6	325	100	464	590	542	94	93½	93	89½
6	325	150	464	590	542	94	93½	93	89½
6	425	150	607	773	710	94	93½	93	89½
8	425	120	607	773	710	94	93½	93	89½
8	425	100	607	773	710	94	93½	93	89½
8	425	80	607	773	710	94	93½	93	89½
8	525	125	750	956	877	94	93½	93	89½
10	525	100	750	956	877	94	93½	93	89½
10	525	90	750	956	877	94	93½	93	89½
10	525	75	750	956	877	94	93½	93	89½
12	850	120	1,206	1,545	1,420	94½	94½	93½	90
12	850	100	1,206	1,545	1,420	94½	94½	93½	90
12	850	80	1,206	1,545	1,420	94½	94½	93½	90
12	1,050	80	1,482	1,910	1,755	95	94½	94	90½
12	1,200	80	1,698	2,180	2,000	95	94½	94	90½
16	1,600	75	2,260	2,910	2,670	95	94½	94	90½

There are, therefore, three distinct types of elevated railway equipment, the steam locomotive using 10 to 15 per cent. of the train weight for traction under heavy traffic conditions, the electric locomotive using 30 to 35 per cent., and the multiple unit system using any amount desired up to 60 per cent. of the train weight.

The transportation expenses of the South Side Elevated Railway, in Chicago, for July, August, and September, 1897, when steam locomotives were employed, were 2.8 cents per car mile, while in the same months of 1898 they were 1.9 cents per car mile, or a saving of nearly 0.9 cent, or about 33 per cent.

METROPOLITAN DISTRICT, LONDON.

Average speed in miles per hour 13½
Maximum " " 27
Minimum time between consecutive trains 2 minutes.
Average time between consecutive trains 3½ to 4 min.
Total weight of train 161 tons.
Average carrying capacity. 450 passen.
Weight of locomotive. 47 tons.
Average distance between stations. 2,600 feet.
Time required in seconds to reach 25 miles an hour starting from a standstill. 30 seconds.

The figures in the above table show at once the great advantage to be gained by electric traction, by means of which speed of 25 miles an hour could be obtained in 10 seconds, and by simple calculation it is

being equipped in New York, and which will operate the two large tramway systems of that city, namely, the Metropolitan and the Third Avenue. The Metropolitan station is now under construction, and will contain eleven direct connected sets each of 3,500 kilowatts, room for extension being allowed, and a capacity having been foreseen of nearly double that amount. The following gives the particulars of the General Electric Company's dynamos which will be used.

The machine will have a frequency of 25 cycles per second, at 6,600 volts. It will have 40 poles, and will run a speed of 75 revolutions per minute. It will be of the stationary armature type, the core being built up of laminations 0.014 inch thick. Each lamination has two dovetail projections which fit in corresponding slots in a heavy cast-iron spider. Spaces are left between the laminations at intervals through which currents of air are driven by the rotating field and circulating by intimate contact with core and windings. The armature winding consists of form-wound coils placed in slots in the core and retained by wooden wedges, the edges of which fit into recesses in the teeth. The field frame consists of a cast-steel ring supported upon a cast-iron spider. To this are bolted laminated core of sheet iron, the pole pieces of which project over and support the copper field windings. The field winding consists of copper strip wound on edge with paper insulation between turns. The insulation is such as to stand a test of 4,000 volts alternating between the winding and the core. The exciting E. M. F. is 125 volts. The collecting rings are of copper, and carbon brushes are used. The armature winding is tested to 12,000 volts alternating. The temperature rise of the

Approximate Weight of Armature and Commutator.	Approximate Weight of Generator Complete.	Diameter of Shaft in inches.	English Rating at 500 Volts Constant Potential.			
			Classification.	Amperes Full Load.	Approx. H.P. to Drive.	Approx. Weight of Steam-engine in lbs.
6,000	13,100	9	150 - 200	300	212	42,500
7,000	21,000	9 - 10½	200 - 180	400	285	50,000
13,900	34,300	9 - 11½	200 - 135	400	285	55,000
14,520	37,000	9 - 11½	200 - 110	400	285	85,000
17,000	45,500	9 - 11½	300 - 135	600	428	144,000
21,000	61,000	11½ - 14	300 - 90	600	428	85,000
25,500	60,000	14 - 16	385 - 135	770	550	94,000
29,000	65,000	14 - 16	385 - 110	770	550	100,000
31,000	72,000	15 - 18	385 - 90	770	550	180,000
32,000	75,000	15 - 18	385 - 75	770	550	198,000
31,000	72,000	16 - 18	480 - 115	960	685	181,000
27,000	69,000	16 - 18	480 - 90	960	685	187,000
32,500	76,600	16 - 18	480 - 80	960	685	192,000
36,000	87,000	16 - 18	480 - 70	960	685	198,000
40,000	100,000	19 - 22	800 - 110	1,600	1,135	215,000
44,000	107,000	19 - 22	800 - 90	1,600	1,135	237,000
47,000	116,000	19 - 22	800 - 75	1,600	1,135	285,000
55,000	130,000	22 - 25	950 - 75	1,900	1,341	300,000
68,000	158,000	24 - 27	1,100 - 75	2,200	1,556	415,000
70,000	160,000	24 - 27	1,500 - 70	3,000	2,120	460,000

machine after ten hours' run at full load is well under 40° C. The efficiencies are as follows:

	Per cent.		Per cent.
1½ load.....	90	1½ load.....	92.5
Full load.....	95.5	¾ load.....	88
¾ load.....	95	Inherent regulation.....	9

The steam engines which drive these dynamos are cross compound Allis vertical engines, 46 inches high and 86 inches low pressure cylinders, and 60 inches stroke. They will develop 4,500 indicated horse power at the rated economical load, and will be able to work continuously at 6,000 horse power if required, and for a short space of time they are to be able to work at 7,000 horse power. The crank shaft is of solid steel, bored and forged, with a hole 16 inches diameter the entire length, and it is 37 inches in diameter where the wheel and armature are located. The diameter of the shaft in the bearings is 34 inches and the length of the bearings 6 inches. The fly wheel will have cast steel centers, and the rim will be built up of steel plates riveted together. The rim will weigh 225,000 pounds, and the engine itself, complete, about 600 tons, and it is believed that as good results as 12½ pounds of steam per indicated horse power will be easily obtained. There will be several sub-stations in which will be located step-down transformers of 300 kilowatts each, which will lower the voltage from 6,600 volts to 350 volts. At this pressure the current will enter rotary converters of 900 kilowatts each, and will be delivered in the shape of a continuous current of 500 volts to the tramway system.

This company operates some 250 miles of tracks and carries approximately 250,000,000 passengers every year.

The Third Avenue road is now engaged in equipping all existing horse and cable lines with electric traction, and for this purpose has just given out a contract for a power station which will eventually contain sixteen 3,000 kilowatt generators. The generators will be very similar to those described above, and are being built by the Westinghouse Company, who are the sole contractors for the whole work. The engines will be marine type, vertical, and are being built by the Westinghouse Machine Company. Sub-stations with rotary transformers will be used, as in the case of the Metropolitan system.

To give an idea of what may be done as regards power transmission, the following few figures may be useful. The first attempts at this class of work were made during the Frankfort Exhibition of 1891, 300 horse power being satisfactorily transmitted a distance of 106 miles with a pressure of 30,000 volts. Since that time electrical power transmission has largely increased, and the results obtained have been very satisfactory. 4,000 horse power at the present moment are regularly transmitted a distance of 85 miles to the city of Sacramento, California, at a pressure of 30,000 volts, where they are transformed into low pressure three-phase and continuous current for lighting, power, and traction purposes. At Telluride, Utah, 1,000 horse power are transmitted 55 miles at a pressure of 40,000 volts; 4,500 horse power are transmitted a distance of 40 miles to Salt Lake City at a pressure of 15,000 volts; 1,400 horse power are being transmitted 35 miles to Fresno, California, at a pressure of 11,000 volts; 2,000 horse power are being transmitted 30 miles to West Kootenay, British Columbia, at a pressure of 20,000 volts; 10,000 horse power are being transmitted from Niagara to Buffalo, a distance of 22 miles, at a pressure of 10,000 volts. All the plants are working and giving satisfaction, and have nothing experimental about them, and there are hundreds more such.

In the designing and carrying out of a large system, there are three points which are frequently overlooked and which may cause a disastrous failure. These are good and adequate bonding; thoroughly good insulation, both mechanically and electrically; and trucks suited for the work for which they are intended.

As regards the bonding, the bonds used should be flexible, but, at the same time, should contain no solder or brazed joint, and they should be expanded against the side of holes drilled in the web or foot of the rail, and held in place by pins. Bonds of this description, when properly applied, can be absolutely relied upon, the contact resistance of the bond with the rail not being greater than the resistance of the solid bond.

With regard to the third-rail insulators, very good results are obtained by using insulating bolts screwed into base plates which are fixed to the sleepers, cast iron chairs being fixed to the head of the bolts to hold the rails.

COMET-PHOTOGRAPHY.

As a general rule a comet appears as a star whose luminous nucleus is surrounded by a more or less bright coma. Nucleus and coma together constitute the head of the comet. Besides the nebulous glare of light, the nucleus of the star is very often accompanied by a train which for various comets and even for one and the same comet varies in length, and which is known as a "tail." There are comets without a tail or luminous nucleus, which are seen merely as globular, nebulous masses. The coma is frequently weakly defined, for which reason the comet is hardly to be distinguished from the other stars. In many comets the tail is branched, and in others several tails may be observed.

The great majority of comets are not visible to the naked eye; and since they can only be seen with the most powerful instruments, they are termed "telescopic" comets. The orbits in which these comets revolve are ellipses, parabolas, or hyperbolas. Comets with elliptical orbits belong to our solar system and are termed "periodic." Comets, however, with parabolic or hyperbolic orbits are not members of our solar system, and are to be looked upon as wanderers from other systems. Such comets are visible to us at the perihelions of their orbits and soon after vanish in space. It can be inferred that many of these cosmic wanderers become members of our solar system after having deviated from their original paths, and that thenceforth they travel in closed orbits about the central luminary.

Comets with closed orbits are divided into three groups. To the first group belong those comets which have a period of revolution of three and a third to seven and one-half years; to the second group be-

long those comets having a period of revolution of sixty-nine to seventy-six years; and, finally, to the third group belong those comets whose periods of revolution number centuries and even millenniums. The elliptical orbits of comets are far more attenuated than those of the planets, and in many cases extend far beyond the path of Neptune. All orbital calculations made before the middle of the last century can be considered as untrustworthy; for the observations then made left much to be desired in the way of accuracy. The following are the most important comets discovered during the last century, with the periods of their revolution:

Comet.	Years.
1811 (I.).....	3.065
1822 (III. Pons).....	5.650
1825 (III. Pons).....	4.386
1840 (II. Galle).....	13.864
1846 (Hind).....	10.818
1857 (III. Klinkerfues).....	7.040
1858 (VI. Donati).....	1.880
1858 (VIII. Tuttle).....	6.000
1860 (III. Gronemann).....	1.060
1864 (II. Tempel).....	4.738
1873 (IV. Henry).....	3.277

The appearance of comets, so far as their size is concerned, is as various as the period of revolution. The diameter of the nucleus can be as small as a hundred

have powerful objectives, of short focal distance and large aperture, and are provided either with an azimuthal or parallactical mounting. The former is generally preferred, because the comet-seeker is mostly used as a portable instrument to be set up under the open sky. One of the most important conditions to be observed in the construction of comet-seekers is that the eye-piece end of the tube should be as short as possible, so that an observer in exploring a large region of the heavens shall not be required to change his position too frequently. In order to meet this requirement, many complicated constructions have been devised.

In the last few years celestial photography has also been applied to comets. Within this period no extraordinary phenomena have been observed, and no mention can, therefore, be made of any particularly prominent performances in this direction. Nevertheless, the photographs which have been obtained can be considered as highly successful attempts in comet-photography. On March 6, 1892, Swift, of Rochester, N. Y., discovered a comet which by the end of the month became so bright that it was visible with the naked eye. It was designated "Comet 1892 (I.)," and was photographed by Barnard at the Lick Observatory. On October 12 of the same year Barnard discovered another comet ("1892 V.") by photography. Of the comet ("1892 VI.") discovered by Brooks in the same year, on August 28, Archenhold, of Halensee, took three photographs, each of twenty minutes' exposure. Viewed

THE COMET-SEEKER OF THE STRASBURG OBSERVATORY.

miles and as large as several thousand miles, these variations being often observed in the same comet. Great as are the variations in the nucleus, still greater are the variations to be observed in the coma. In Halley's comet the diameter of the coma, when observed in 1835, was seventy thousand miles, and in the comet of 1811, fully twenty-five thousand miles. The form and dimensions of the tail also vary to an extraordinary extent. In the comet of 1858, for example, the tail was eleven million miles long, in that of 1848 fully forty-five million miles. The width of the tail is smallest at the head and greatest at the opposite end and is, as a whole, far more constant than the length, which very often varies in exceedingly short intervals of time.

Owing to the elongated form of many comet orbits, exceedingly small perihelion distances are produced. For example, the comet of 1680 approached within thirty thousand miles of the sun, that of 1843 (I.) within nineteen thousand miles. The former in aphelion was distant from the sun seventeen thousand million miles and here passed through only three meters of its orbit in a second; while in perihelion it passed through fifty-three miles in the same time. Most of the observed comets, when in perihelion, are distant from the sun less than the diameter of the earth.

Telescopic observations of comets are best made by means of so-called comet-seekers. These instruments

through the comet-seeker, the tail of this comet was only one-half a degree long; upon the photographic plate it was five degrees long. Later this same comet was photographed by Liais, of Rome. At the Lick Observatory, Prof. W. J. Hussey has taken a whole series of photographs of Rordame's comet (1893 VI.) These interesting photographs were made by means of a portrait lens of six inches aperture and focal length of thirty-one inches. The plates used were 8×10 inches in size. Enlargements made from these negatives show a rather large nucleus surrounded by a coma one-quarter of a degree in diameter and almost globular in form.

The first successful photograph of a comet was made in 1881 by Dr. Draper, of New York city, who photographed Tebbut's comet ("1881 III.") An exposure of two hours and forty-two minutes produced a negative which showed the nucleus and ten degrees of the tail, as well as many smaller stars. Several days later, Draper photographed the spectrum of the comet after a similar attempt had been made by Huggins, on June 24, 1881. The photographs of the comet of 1882, the brightest and largest which had appeared since 1858 (Donati's comet), showed a noteworthy progress. The interest taken in these labors was small; for celestial photography at that time received but little attention.

It has been demonstrated that many comets change