

borax. This black, glassy mixture is pulverized, and the powder spread on the seam.

It only remains to mention the so-called cold-soldering, in reality a joining of the edges by means of a copper amalgam. The parts to be joined are well cleaned, and a substance made by triturating 1 part of metallic sodium with 50 to 60 parts of mercury rubbed in. This substance may to some extent be used for the same purpose as soldering fluid, as it causes the firm adhesion of the copper amalgam employed as solder.

To make copper amalgam, dissolve copper sulphate in water and add some zinc-plate chips. A fine powder consisting of pure copper is deposited, which should be filtered off, washed, and triturated in a heated porcelain bowl with a double quantity by weight of mercury. The amalgam, which resembles 18-carat gold in color, is formed into little pellets or bars, which are made soft by heating when required for use.—*Deutsche Goldschmiede Zeitung*.

SOME EXPERIMENTS WITH THE MERCURY ARC.*

By EMILE GUARINI.

AFTER the admirable experiments made by Mr. Cooper Hewitt and the brilliant results obtained by him, it was but natural that extensive researches upon the mercury arc should be undertaken. All the investigations in this domain are most interesting and equally so are the experiments recently made by Lieut. de Valbreuse, which are illustrated in the accompanying figures, for which the writer is indebted to the courtesy of the editor of *L'Eclairage Electrique*.

from 4 to 2 millimeters, and the tension at the terminals from 450 to 200 volts. There occurs a transfer of mercury from the anode to the cathode, and a condensation of the vapors into small drops at the anode and into large ones at the cathode.

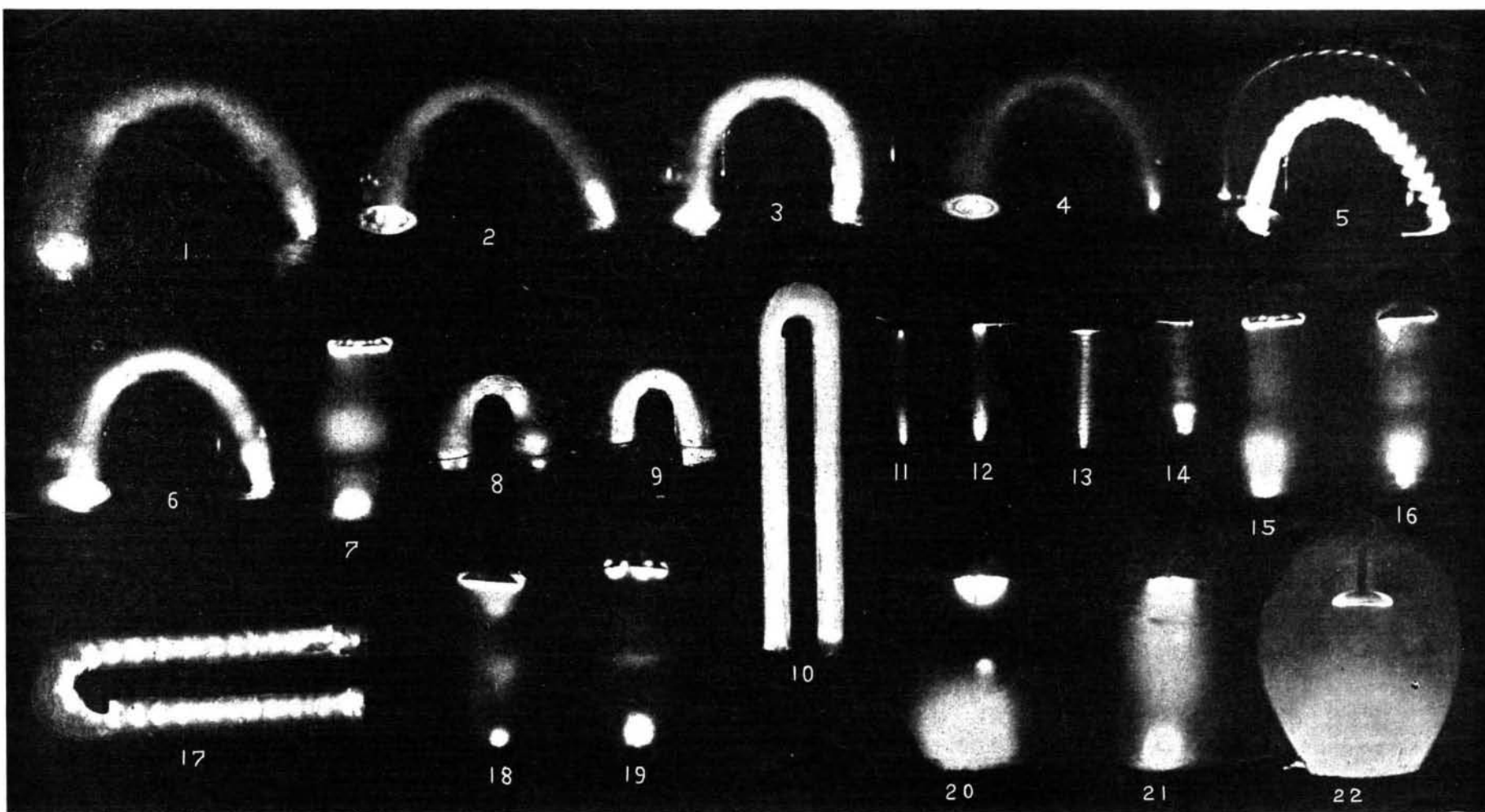
Between 1.5 millimeter and 0.05 millimeter, and with a current of less than 0.4 ampere, the luminous vein is completely striated and forms a succession of rings like those of a caterpillar (Fig. 5). The anode is at first capped with a very luminous cone, which afterward becomes converted into a disk that slowly reaches the cathode, followed by other and similar disks. The rings, after the series of them is once formed, are nearly stationary in space, but tremulous and undulating (Fig. 7). Above 0.4 ampere, the striæ disappear. In proportion as the pressure diminishes, the rings become thick and finally consolidate. The production of striæ is analogous to that exhibited by ordinary vacuum tubes. It is explainable, it seems, only on the theory of a series of alternate contractions and expansions of the gaseous medium.

Below 0.05 millimeter the striæ become consolidated and disappear (Fig. 8). Above the luminous spot that surmounts the negative star, there is produced a dark space which becomes more and more elongated (Fig. 9). If the current be then increased by 5 or 6 amperes, the difference of potential at the terminals will fall abruptly to about 15 volts and remain at that figure. It establishes itself as a function of the pressure and also of the temperature and current. The minimum current necessary for the maintenance of the arc increases in proportion as the pressure decreases, and passes from 0.15 to 0.5 and even to 1 ampere. If the energy expended is not too great, an

Its color is at first violet, and it is very thin (Figs. 11 to 14). The extra starting current, however, will jump through the tube as soon as the pressure descends to 15 millimeters. It is impossible to start the arc by taking the mercury as anode and the iron as cathode. Since the anode is not continually cooled by the vaporization of the mercury, it becomes greatly heated. Despite the long and thick iron rod that forms the anode, the platinum wire that connects with it attains such a high temperature as to often break the glass where it passes through it.

The phenomena observed in these arcs have the same general trend as previously. The anodic stars seem to exist, but are rare and difficult of observation with equal pressures. The starting is easier than in tubes using mercury alone. At all degrees of vacuum the phenomena of self-starting at 550 volts are met with, provided that the tube be slightly warm when the pressure is very low (Fig. 22). At pressures comprised between 0.6 millimeter and 0.15 millimeter the phenomenon is manifested by a superb violet light that seems to float 5 millimeters above the cathode, and by a dim, greenish light that borders the anode. The arc almost always starts spontaneously at the end of a few minutes at the pressures at which vacuum tubes exhibit their maximum conductivity. At lower pressures, the preliminary phenomenon is always the same; but the cathodic light diminishes in intensity and becomes white, the spontaneous excitation becomes rarer, and a shock is necessary to produce the normal passage of the arc.

Whenever a tube does not start readily, the difficulty may be overcome by shaking it. Tubes which, on account of too great a vacuum, often offer an insur-



EXPERIMENTS WITH THE MERCURY ARC.

These show the various aspects that the mercury arc exhibits, according to the extent of the pressure in the interior of the receptacle in which it is produced. The pressure is measured in millimeters of mercury. The first experiments were made upon two kinds of tubes, viz., those with two electrodes of mercury, and those with an anode of iron and a cathode of mercury. In the first, the arc begins to remain stable when the internal pressure is 4.2 millimeters. The difference of potential at the terminals is 450 volts for a current of from 0.3 to 0.4 ampere. The color of the arc is bright red at the outset, but this quickly becomes a violet-rose hue, and finally white.

At the start the anode has a uniformly luminous appearance, but it soon becomes covered with extremely brilliant little stars forming regular and changeable geometrical figures (Figs. 1 and 2). If the current be interrupted, the location of the stars will be marked upon the surface of the mercury by black points of oxidation. The size of the stars increases in proportion as the electrode becomes heated. Each one often assumes the form of a luminous spherical bead of the size of a pea lying upon the surface of the mercury. The stars afterward become conglomerated into a disk surrounded by rings (Figs. 3 and 4). The thickness of the dark intermediate rings gradually diminishes and nothing remains but a uniformly luminous surface (Fig. 6).

During this time the violaceous hue of the arc leaves the cathode and slowly reaches the anode, whence, in a few seconds, it entirely disappears. The arc is then of a milky white. The pressure has fallen

equilibrium will be exhibited, and it will be possible for the tube to operate for a very long time (Fig. 10). If, on the contrary, the current be too intense for the radiating surface of the walls, the glass will become heated, the internal pressure will rise above 10 millimeters, the arc will become unstable, the fall of potential will increase, and the intensity will diminish (Fig. 9). Finally, the glass will become soft and be pierced. It is well not to lower the pressure in the tube below 0.005 millimeter, since below this figure the starting of the tube becomes very difficult. In fact, unless we have very large self-induction coils to use, it is scarcely possible to obtain a difference of potential greater than 7,000 or 8,000 volts at the terminals of the tube. For starting the tube, however, it requires about 3,500 volts for 2.5 millimeters of pressure, 1,500 for 1.5 millimeter, 800 to 100 for 0.05 millimeter, 5,000 to 6,000 for 0.01 millimeter, and 8,000 for 0.006 millimeter. When the pressure is comprised between 6 millimeters and 15 millimeters and the electrodes are slightly warm, more or less complete self-starting phenomena occur. Upon submitting a tube, without starting it, to a difference of potential of from 550 to 600 volts, a violet stratum forms at a few millimeters above the cathode and a greenish arc above the anode. The light often fills a part of the tube. The current that passes is then from 0.01 to 0.02 ampere. Sometimes, the normal arc succeeds in forming spontaneously. A slight shock generally suffices to bring about the passage of the arc in other cases.

With tubes having an iron anode and a mercury cathode, the spark leaps between an iron cup and a mercury cup placed in a glass bulb. It remains stable only when the pressure is less than 5 millimeters.

mountable obstacle to the current, are sometimes easily started when the surface of the mercury is agitated while the interrupter is operated rapidly. The results obtained by jarring the tube are to be explained, according to Lieut. de Valbreuse, by the presence of a superficial membrane that offers an opposition, especially when cold, to the passage of the current. He explains in the same way the production of the rings and stars above mentioned, which are produced in the tubes using mercury only.

The arc between iron and mercury, during almost the entire operation, exhibits striæ starting from a luminous sheath that surrounds the anode. Such striæ, which are at first compact, become spaced wider and wider apart in measure as the pressure decreases. They are always very movable and tremulous. When the vacuum has advanced to a certain point, there is no longer anything produced but a single stratum in the form of a dish with upturned edges that occupies the center of the tube (Figs. 15, 16, and 17). If the intensity of the current be raised to 4 or 5 amperes, the striæ will always make their way toward the anode and seem to concentrate themselves there into a luminous ball (Fig. 20).

When the pressure is very low and the current weak, the glass flask is entirely filled with a light gray homogeneous light of but slight luminosity. If the strength of the current be increased, the light will become more intense, but be localized in the vicinity of the two electrodes, the rest of the tubes being nearly dark (Figs. 18, 19, and 20). When the intensity exceeds 10 amperes, the arc is continuous and very luminous, and the anode becomes red and melts at the edges (Fig. 21). In a short time the heating brings about a

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

super-pressure, and the arc becomes thin and very unstable.

All these phenomena are, as may be seen, very interesting; and will perhaps make valuable contributions to the knowledge that we already possess upon the difficult subject of discharges in vacuum tubes.

PROGRESS IN THE USE OF ELECTRICITY.

We have time and again referred to the fact that the principal obstacle to the general use of electricity has been that created by the municipal authorities; who, while themselves frequently unwilling to embark on the somewhat speculative procedure of constructing central stations for the public supply of electric energy, have imposed such difficult terms upon private enterprise that it became hazardous, even for capable promoters, to undertake the supply. Parliament assisted in the entrenchment of local authorities; and it is certainly a tribute to the commercial instinct and progressive energy of capitalists in this country that electricity has now such a firm hold. Unfortunately, however, these splendid commercial traits of character have not altogether had their reward, because, although private companies demonstrated the superiority—alike as regards illumination and economy—of electricity, they have not, taking them in the aggregate, had the recompense that was their due. The areas which were reserved, as the result of Parliamentary and corporate action, were naturally the most lucrative; and thus, if we except the metropolis, most of the large electrical undertakings in the country are municipal enterprises. The result is that, in later years, the progress, as measured by the number of the Board of Trade units sold, is very much greater in the case of municipalities than in that of companies. Thus, of the thirty million units sold in 1896, two-thirds were produced by companies; in 1899, the municipalities and the companies each generated one-half of the 85 million units used; and for the past year the municipalities have produced two-thirds of the total of 344 million units. It will thus be seen that the output from municipalities has increased at a very much quicker ratio than that from company power-stations. Last year marked an increase of practically 100 million units on the total quantity sold in the United Kingdom, and of these 78 million units were credited to the undertakings of public authorities. It should, however, be made clear that there are 226 municipal stations, as compared with 130 company schemes; so that the average annual output per corporation station is considerably greater than the mean output from the companies' stations—1,030,000 units as compared with 856,000. But an indication of the superiority of the town stations is afforded by the fact that the total units sold in 1903 per 8 candle-power lamp in the case of municipal stations was 23, as compared with 16 for company stations; the mean annual amount of electrical energy consumed in the United Kingdom per 8 candle-power lamp, being practically 20 Board of Trade units.

The cost of generation is decreasing; the details given in Garcke's "Manual of Electrical Undertakings"* show that, in the case of sixty undertakings in 1896, the total cost per Board of Trade unit, exclusive of depreciation, interest, sinking fund, and capital charges was 4.07d.; it was reduced in 1900 to 2.67d., in the case of 118 stations; last year it was only 2.30d., although 216 were included in the analysis. Under the head of generation alone the reduction has been 1d., from 2.45d.; while under the head of distribution it has been equally satisfactory, from 0.36d. to 0.21d. Although the companies have not the same lucrative business as the local authorities, they have, by economy and by liberal action toward the consumer, maintained a fairly good dividend, although the rate has been decreasing in recent years. Apart from the 27.79 millions sterling borrowed by municipalities, the total capital invested in electric light and power companies is now about 24½ million sterling, of which 28 per cent is on loan and debenture capital, the average return on which is 4.43 per cent, which marks a decrease from 4.69 per cent in 1897; 21 per cent is preference capital, and here the decrease in the rate is more marked: from 6.05 per cent in 1897 to 5.36 per cent in the past year; but this latter figure shows a slight recovery on the totals of the two preceding years. The ordinary capital, which represents about half the total invested in electric light undertakings, earned last year an average of 5.29 per cent. This is necessarily a fluctuating return, owing largely to the beginning of new stations, involving, as they do, a capital expenditure without any immediate return on ordinary stock. Naturally, the demand has to be cultivated; it is in the development of this demand that the private company excels the corporation; and the practice, which is adopted now in many cases, of the company putting in a wiring and charging a rent, has certainly increased materially the use of electricity. It would assist matters still further if some such arrangement could be made whereby, after the lapse of a certain period of time, this rent should cease; and an even more extensive development would follow if the companies could induce the owners of houses to put in the wiring in all existing property (under an agreement with the tenant), whereby the cost might be spread over a period of ten years, instead of the tenant, whose occupancy is determinable upon a three years' lease, being called upon to bear the expense.

In electric traction we find a corresponding development has taken place. Mr. Garcke, in his admirably-

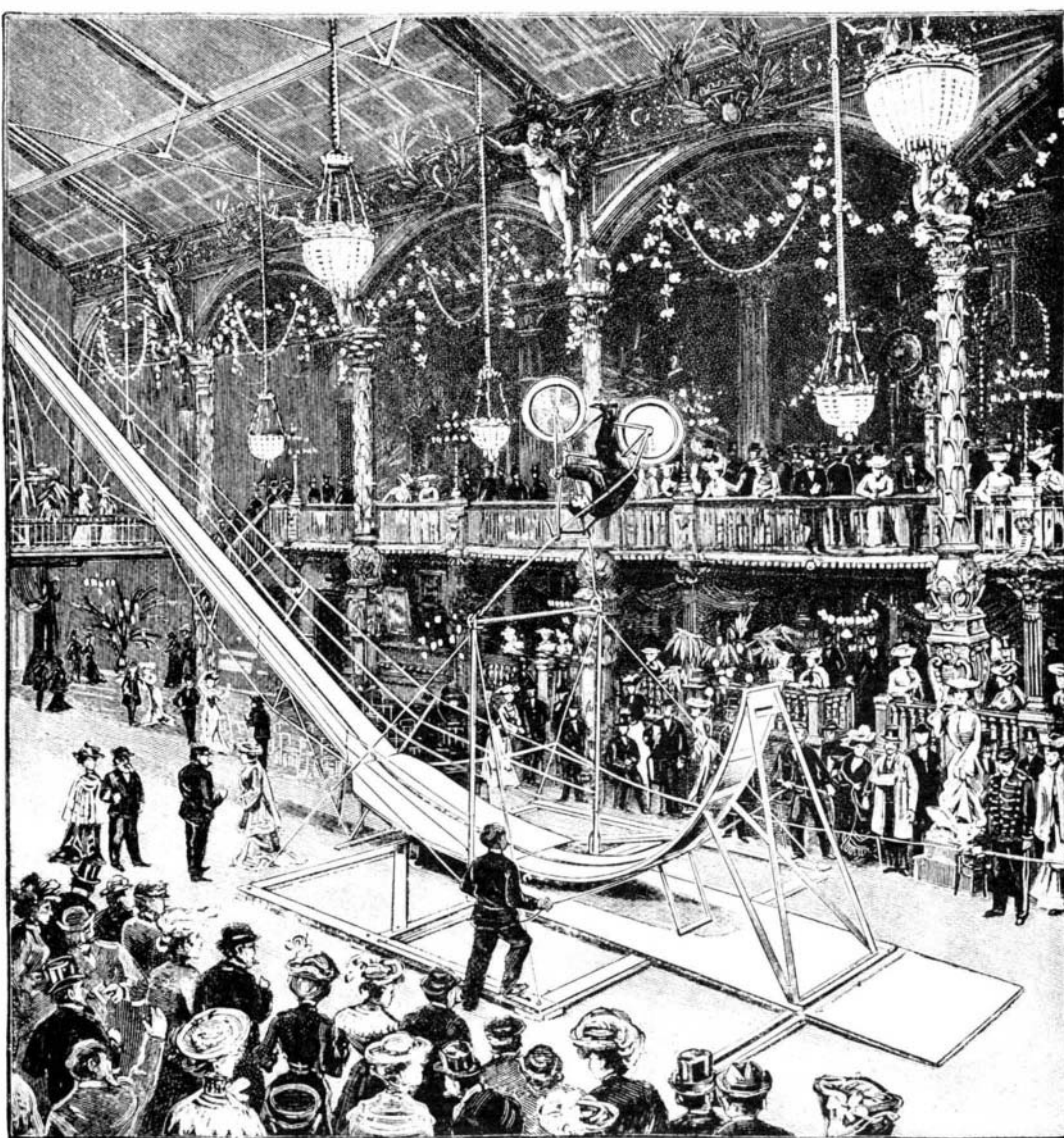
arranged details, shows that the total capital of 156 electric traction undertakings is now £61,606,509, which is 17 million more than in the previous year, and ten times the total of eight years ago. Municipal undertakings, however, are still in a minority; for here, more than in lighting, the municipalities have hindered development by refusing to grant a renewal of the leases to old companies, so that they might with some degree of security of tenure apply the new method of haulage to their existing lines. This refusal has delayed the development of electric tramways long after untrammelled private enterprise had carried out schemes in less populous places. There are now 92 municipal undertakings, with a loan capital of 21¼ million sterling, which is a little more than one-third of the amount involved in company schemes. The total mileage of electric tramways and light railways in 1903 was 5,348 miles of single track, and 3,584 route miles; the former showing an increase of 633 miles, and the latter of 368 miles as compared with the previous year. The number of cars in use has increased in one year from 5,528 to 7,343. As to the return of capital for the electric traction schemes, it may be noted that of the 61.6 million sterling, 24 per cent is loan and debenture capital, and on this the return for the past year has averaged 4.53 per cent, which is about the mean for the past five years; 22 per cent of the total is preference capital, the return on which has been 4.81 per cent, showing a slight decrease during the past five years; the remaining 54 per cent is ordinary capital, on which the return has been 4.13

enormous amount of close upon 227 million sterling. This is exactly double what it was four years ago. It would appear from an examination of the average rate of dividend on capital invested that manufacturing is the most profitable, as the average rate in this case is 5.85 per cent; for telephones, 4.80 per cent; for telegraphs, 4.76 per cent; and for traction, 4.41 per cent. In view, however, of the speculative nature of the undertakings, and of the large amount of propagandist work that must be done before final success is realized—apart altogether from the great uncertainty consequent upon municipal aggrandizement—this return can scarcely be regarded as high, although under the circumstances it is satisfactory.—Engineering.

DOING THE "GIANT SWING" ON A BICYCLE.

UNDER the name of the "Human Whirlwind," the Paris Casino is offering a new attraction that might better be called the "human sling," since here a bicyclist and his machine, suspended from the end of a rope, describes a complete circle without the necessity of any track such as is used in the exhibition of "looping the loop."

Things are arranged as follows: The track necessary to give the proper speed is, as usual, a long inclined plane, the upper end of which nearly touches the ceiling of the immense hall of the Casino, and which, after descending nearly to the floor, turns upward in the form of a semicircle, but only to a height of about 8 feet. At the bottom there are two



THE HUMAN SLING.

per cent. But, as a matter of fact, 5 million sterling of the ordinary capital for traction has not yet reached the dividend-paying stage, whereas in the case of lighting only 1¼ million sterling receives no dividend; so that it may be assumed that traction is in a more experimental stage from the commercial point of view than lighting.

In addition to the mileage given there is 18¼ miles of deep-tunnel railways in London now in operation; 26½ miles under construction, 91 miles in process of conversion to electric traction, and 19 miles authorized. The total for the metropolis alone is 154¼ miles, as compared with 58¼ miles a year ago. It is further interesting to note that the electrification of standard-gauge surface railways, to the extent of 127½ miles, is either in course of construction or has been authorized; the mileage authorized, but not yet commenced, making up a total of 47 miles.

In addition to supply and traction undertakings, a very large amount of money is invested in electric schemes. Thus, there are 35¼ million sterling devoted to manufactures, showing an increase of six million sterling as compared with the preceding year, and of ten million sterling compared with two years ago. On telegraphs there are 33½ million sterling invested, and on telephones 10½ million sterling, of which only £318,000 sterling is due to municipal undertakings, three in number. Miscellaneous schemes involving 12 million sterling bring the total subscribed capital of all electric undertakings, numbering 1,121, to the

posts 13 feet in height, which are rigidly placed and are provided at the top with specially-shaped hooks to which are fastened the ends of a rope that hangs in the form of a V between them. Again, the bicycle carries a frame that extends to a height of about 12 inches above the head of the rider, and is provided on each side with a large hook, which is designed to engage with the rope at the moment at which the velocity of the machine is at its maximum. The bicycle and its rider, after descending the inclined plane, continue their course for an instant upon the semicircular part of the track, and then, held by the rope, finish describing the circle in the air. At the moment at which the wheels of the bicycle resume contact with the ground, the rope becomes detached automatically, owing to the special form of the hooks that sustain it at its ends, and it is possible for the bicyclist to continue his journey in a straight line, the curved part of the track having been removed and the straight part lowered to the level of the ground during the short time that he was in the air. The curved part is mounted upon two rails on which it is slid to one side, and the level part is supported by a metallic horse that is folded up when the pedal is pressed by the attendant. These two parts are manipulated at the same time by one man.

In "looping the loop," the bicyclist, at the proper moment, has to turn his handle bar so as to cause him to deviate slightly from a straight line in order to follow the helicoidal track that permits him to make

* "Manual of Electric Undertakings and Directory of Officials," compiled under the direction of Emile Garcke. Vol. viii. London: Publishing offices, Mowbray House, Norfolk-street, Strand, W.C., 1904.