

Lancaster, but that he has never succeeded in floating one of these "wings" so that they would advance against the wind. Once, to his knowledge, tested the matter, and had no better success, yet it is not rational to say that the test is impossible, for it is very clear that if the wind have an ascending trend, and the "wing" be slightly tipped toward the front, the horizontal component of air pressure will drag it forward, while the vertical component will sustain or elevate it, as already explained. It is probably because of the uncertain prevalence of ascending trends that Mr. Lancaster complains that sometimes almost all these toys would succeed in simulating soaring, and sometimes none at all.

In 1888 Mr. Lancaster moved to Colorado, where he has been experimenting with a view to the solution of the problem of soaring flight; and in the *American Naturalist* for September, 1891, he gave an account of some of his experiments, with the conclusions which he deduced therefrom. The following extract contains an account of a remarkable occurrence. He says :

I can produce true soaring flight in natural wind, with a plane exceeding 2 lbs. to a square foot of surface, whenever I wish to do so and can obtain wind strong enough for the purpose. During the past three years I have made about 50 planes [aeroplanes?] of various shapes and sizes, and from 25 lbs. to 400 lbs. in weight. These planes are not set free in wind, but used in the experimental cases above described, but with rigid rods in place of the parallel wires. These rods run in large rings and have a cross-haul at their outer ends allowing the plane to run to the front until its edge rests against the rings. In the last trial the parallel [with the plane?] component is neutralized at 10° from horizontal, far exceeding my expectations derived from observations of the birds, their angle of obliquity being rarely over 5°.

On a few occasions these planes accidentally escaped me in time of highest wind, and were ruined at once for all purposes excepting firewood, in each case being a loss of two or three months' work, and playing havoc with my finances. One that I valued particularly plunged to the front in a violent blast of wind with force sufficient to tear out the rings. It rose into the air, gradually higher and higher, until an elevation of at least 3,000 ft. was attained, when some part of the device giving away, it lost equilibrium and plunged through the air, striking the earth about 2½ miles from the starting-point, and 1,000 ft. higher than that locality. Another mile would have carried it to the summit of the Flat Top Mountains. It was in the air about three hours, and I walked beneath it during its flight. Its course was directly against the highest wind I have experienced during my residence here. At times it did not progress, but went higher. It weighed 110 lbs., and had been well balanced for experimenting on surface manipulation. There was no lesson taught in this flight, the birds having been doing the same thing for a long time. It was an interesting spectacle to look at; so is a large bird in the same act. I presume Mr. Darwin's provisional solution would apply to this plane as well as to the condors; but I am trying to explain the actual mechanical activity of both.

The best effects produced were with a plane of 400 lbs. weight and 80 sq. ft. of surface. In a wind that would be rightly termed a gale, rising about midnight, this plane was thrown about 7° from horizontal. It ran to the front against the rings at 10°, where the entire parallel component was neutralized, and at 7° it hugged the rings with a force that required a backward pull of 15 lbs. to detach it.

This plane would make a splendid navigator, and I would have no hesitation in trusting myself to it, when soaring, equilibrium and alighting or stopping items had been worked out. I mean to say that it would navigate wind. I am now just entering on a course of experiments in calm air.

This very interesting case of "aspiration" may have been produced by the same cause as in the case of M. Myer's kite—i.e., an ascending trend of wind; but certainty concerning this depends upon the shape of the surface. Mr. Lancaster writes of it as a "plane"; but as he mentions also the "front ledge" and the "rear curve," the surface operated upon by the wind was probably a more or less compound surface, for which there is no specific name, but which may be described as an aeroplane. If it was shaped like those of the soaring birds, then "aspiration" might occur with a horizontal wind, but the equilibrium would be very unstable, and, as Mr. Lancaster points out, the steering, alighting, and stopping would be the important points to work out.

Among the most systematic and carefully conducted series of experiments that have ever been made in the direction of artificial flight are those of Herr Otto Lilienthal, of Berlin, Germany, a mechanical engineer and constructor, and a prominent member of the German Society for the Advancement of Aerial Navigation.

The general position that he maintains, and in pursuance of which he has made his more recent experiments, is that bird flight should be made the basis of artificial flight. Dexterity alone, as he maintains, invests with superiority the native denizens of the air, and, therefore, man, if he possessed sufficient skill, might participate in flight. He evidently believes, like M. Mouillard, that for the soaring birds, ascension is the result of the skillful use of the power of the wind, and that no other force is required; and, therefore, that to imitate them no engines or other external sources of power are needed, but that all the necessary apparatus consists of properly constructed sustaining surfaces skillfully operated.

Herr Lilienthal, instead of first flying at conclusions, began by a systematic analysis of the problem, verified by experiments, which latter were carried on by himself and his brother, O. Lilienthal, during a period covering nearly 25 years, and he published in 1889 a book on "Bird-Flight as the Basis of the Flying Art,"* in which he gave the result of his investigations.

From a review of this remarkable book in the *Aéronautique* for January, 1892, the following account of its contents has been prepared.

Herr Lilienthal seems to have begun by observing the sailing of various sea birds following vessels at sea, and of the stork, an expert soarer, which inhabits Germany; he drew the conclusion that plane surfaces present undue resistance, and that success in artificial flight is only to be expected from concavo-convex sustaining surfaces; a belief which, as we have already seen, was also entertained by Le Bris, Besan, Goupil, Phillips, and others.

He declares that the laws of air resistances and reactions which, unfortunately, are as yet but imperfectly known, form the whole basis for the "technique" or actual performance of flight, and that the shapes and methods of birds so completely utilize these laws and offer such appropriate mechanical movements that failure must follow if they be discarded.

Herr Lilienthal's experiments were in great part directed toward an investigation of the resistances and reactions of air, and the power necessary for flight. One of these consisted in suspending himself from a spar projecting from a house and operating a set of six wings opening and closing like concave Venetian blinds, through which he measured the lifting effects of wing strokes performed with the muscles of the legs, so that the step of each foot would produce a double stroke of the wing. The weight of the operator and wings combined was 170 lbs., and they were counterweighted with 68 lbs. suspended to a rope passing over two pulleys. With some practice he was enabled, by operating the wings with the pedals, to lift himself 30 ft. from the earth, thus proving that he obtained, through his mechanism, wing power sufficient to lift the remaining 88 lbs.—a very excellent performance, and much in excess of most of those hitherto described in this review of Progress in Flying Machines.

This and other experiments, together with a consideration of the power to be obtained from the wind, convinced him that artificial flight was accessible to man, aided by considerably weaker motors than have generally been thought indispensable, and, indeed, under favorable circumstances of wind, with no motor at all.

Herr Lilienthal, therefore, carefully analyzed the shapes and methods of the living birds and the exact proportions of their concavo-convex surfaces. He went into this in detail, and finally formulated in his book the following conclusions :

1. The construction of machines for practical operation in nowise depends upon the discovery of light and powerful motors.
2. Hovering or stationary flight without forward motion cannot be compassed by man's unaided strength. This mode of

* "Der Vogelflug als Grundlage der Fliegekunst," Von Otto Lilienthal, Berlin, 1889.

flight would require him to develop, under the most favorable circumstances, at least 1.5 horse power.

3. With an ordinary wind man's strength is sufficient to work efficiently an appropriate flying apparatus.

4. With a wind of more than 22 miles per hour, man can perform soaring or sailing flight by means of adequate and appropriate sustaining surfaces.

5. A flying apparatus, in order to operate with the greatest possible economy, must be based, both in shape and proportion, upon the wings of the large, high-flying birds.

6. The sustaining wing surface may be from 0.49 to 0.61 sq. ft. per pound of weight.

7. Sufficiently strong apparatus can be built of willow frame and stretched fabric, so as to provide a sustaining surface of 107 sq. ft., with a weight of about 33 lbs.

8. A man provided with such an apparatus would have an aggregate weight of 198 lbs., and would then have 0.55 sq. ft. of sustaining surface per pound, or about the proportions of large birds.

9. Experiment must determine whether the most advantageous shape be that of birds of prey and of waders, with



FIG. 73.—LILIENTHAL—1891.

broad wings and spread out primary feathers, or that of sea birds, with narrow wings tapering to a point.

10. If the broad wing be adopted, the wings of an apparatus with 107 sq. ft. of sustaining surface would needs be of 26.25 ft. spread, with a maximum width of 5.25 ft.

11. If the narrow wing be adopted, a surface of 107 sq. ft. would need a spread of 36 ft. with a maximum width of 4.00 ft.

12. The application of an additional bearing surface, as a tail, is of minor importance.

13. The wings must be curved in transverse section so as to be concave on the under side.

14. The depth of flexure should be one-twelfth of the width, in order to correspond with that of birds' wings.

15. Experiment must determine whether greater or lesser flexure will prove preferable for larger wing surfaces.

16. The framing and spars of the wings should be at the front edge so far as possible.

17. A sharp cutting edge should terminate this framed front edge if possible.

18. The flexure should be parabolic, the greater curvature being to the front and flatter to the rear.

19. The best shape of flexure for large surfaces must be determined by experiment; also what preference is to be given to those shapes which produce the least resistance to forward motion at flat angles of incidence.

20. Construction must be such as to admit of the rotation of the wing upon its longitudinal axis, which rotation will best be obtained, in whole or in part, by the pressure of impinging air.

21. In flapping flight the inner wide portion of the wing should oscillate as little as possible, and serve exclusively in sustaining weight.

22. The propulsion to maintain speed should be obtained by up-and-down beats of the wing tips or of the primary feathers, the forward edge being depressed.

23. In flapping flight the widest portion of the wing must also co-operate in the upstroke in order to sustain weight.

24. The wing tips should encounter as little resistance as possible on the up stroke.

25. The down stroke should be in duration at least six-tenths of the time occupied by the double stroke.

26. The wing-tips alone need oscillate; that portion of the wing which merely sustains may remain rigid, as in soaring flight.

27. If only the wing-tips oscillate they should not be articulated, as this would dislocate them; moreover, the transition to the up stroke should be as gentle as possible.

28. In order to beat a pair of wings, man must employ his extensor muscles, and this not simultaneously, but alternating each side, so that each stroke of the foot shall produce a double stroke of the wings.

29. The up stroke may be produced by the pressure of the air under the wings.

30. The energy of the air pressure under the wings may be partly stored in a spring so as to restore the power on the down stroke, and thus produce economy in work done.

Such are the principal considerations which must be observed in the application of the theories herein expounded.

Governed by these considerations, equipped with much preliminary experiment and analysis, Herr Lilienthal put his theories and conclusions to practical test, in the summer of 1891, by undertaking a series of experiments with a pair of curved wings designed for soaring alone—that is, to serve as sustaining surfaces and not for flapping or propulsion.

The following account of these experiments has been furnished by Mr. George E. Curtis, of Washington, D. C., who has also obtained from Dr. C. Kosane, of the Meteorological Institute at Berlin, the very graphic photographs from which the engravings have been made.

The Lilienthal apparatus is shown in fig. 73, and consists of a pair of extended bird-like wings, incurved from front to back on parabolic lines, and sinuous in the direction of their lengths. The area of sustaining surface, as at first constructed, was 107 sq. ft., but it was diminished in the course of numerous changes and remodelings to 86 sq. ft. There was, as will be observed, a horizontal tail and a vertical rudder or keel. The framework was made of willow, and covered with sheeting fabric. The weight of the whole apparatus, without the operator, was 33.6 lbs.

In order to become accustomed to the management of these artificial wings, Herr Lilienthal first practised in his garden. Here he had a spring-board, toward which he ran for a distance of about 25 ft.; and with the velocity thus acquired, together with the reaction of the spring-board, he launched himself into the air, where he could learn to operate and to manage the wings.

After these preliminary experiments had given him dexterity and facility in the management of the apparatus, he betook himself to a hilly region in the suburbs of Berlin, and there practised soaring flight in natural winds of moderate velocities. The plan, of course, consisted in first running against the wind, and thus deriving therefrom the necessary sustaining air pressure.

Having selected a hill whose downward inclination faced the prevailing wind, he ran along the summit straight toward the wind, until a sufficient velocity was attained at the brow, where he was carried into the air and landed safely at the foot of the hill, having sailed a distance of 65 to 88 ft.

When the wind velocity became greater than 11 to 13 miles

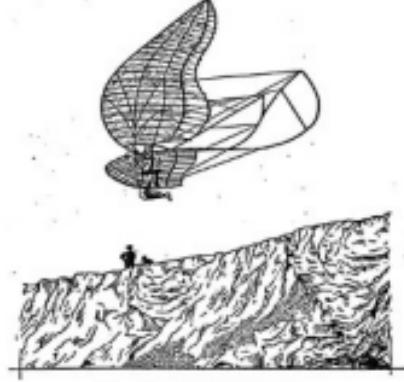


FIG. 74.—LILIENTHAL—1891.

per hour, the management of the apparatus became exceedingly difficult, and Herr Lilienthal advises an experimenter not to venture to leave the ground under such circumstances, unless he has attained, through long practice, a considerable degree of dexterity in maneuver.

The results attained in the practice of the season of 1891 were sufficiently encouraging to warrant the further prosecution of these experiments in the following year; but they disclosed a number of points to which additional attention

needed to be given in order to overcome the practical difficulties in imitating the birds. These points related to a better adjustment of the center of gravity, to methods for obtaining greater stability, and to the mode of management of the apparatus when the wind blew more rapidly than 11 to 18 miles per hour.

In the issue of the *Zeitschrift für Luftschifffahrt* for November, 1892, Herr Lüddecke published an article on "Soaring and its imitation," in which he gives a brief account of his experiments in the summer of 1892, from which the following abstract has been prepared:

Many theories have been proposed to explain soaring. My own explanation is based upon the advantageous relations of air resistance incident to the use of slightly curved wing surfaces (as I have demonstrated) and upon the gently rising trend of air current which I have found to prevail.

A flying apparatus which has the same properties as those of a good soaring bird and is of sufficient size to carry a man can scarcely be held fast by three or four men together when exposed to a brisk wind. When we look at the safe and quiet sailing of the birds it almost seems as if some undiscovered mechanical principle were at work, some feature in the elastic properties of air or in the elastic curvature of the feathers which accounts for the mystery of sailing flight; but my experiments have taught me that there is no mystery, and that the same mechanical science which has explained the theory of the steam-engine and followed the orbits of the planets is adequate to explaining the operations of soaring flight.

Dexterity alone, in my opinion, invests the native inhabitants of the air with superiority over man in that element. . . . Inasmuch as continuous soaring with large wings in high winds can terminate in scarcely anything but the destruction of the foolhardy fellow who may first attempt the experiment without previous practice, I first undertook last year to gain some experience with a smaller apparatus and in moderate winds. In spite of my caution the wind several times played the mischief with me. Even with only 86 sq. ft. of sustaining surface, I was several times tossed up into the air by unexpected gusts of wind, and but for the circumstance that I was able to release myself quickly from my apparatus, I might have had a broken neck instead of the sprains in feet or arms which always healed in a few weeks.

Almost every Sunday, and sometimes on week days, I went out to practice on the hill between Grosskrotzen and Wuster. A mechanic, Herr Hugo Küllitz, the maker of my apparatus, went with me, and each practised alternately while the other rested. Thus we obtained dexterity in gliding down on the air and in landing at the foot of the hill without mishap.

Herr Kassner, of the Meteorological Institute, was so kind as to photograph me in the air, and thus enabled me to exhibit to the members of the society how I sailed right over the head of the miller of Derwitz (in whose barn I stored my apparatus) and of his esteemed poodle dog.

Equipped with the experience gained in 1891, I this year attempted to soar with wings measuring 172 sq. ft. in surface. My apparatus weighed 53 lbs., and my own weight is 176 lbs., so that the whole was 229 lbs. Each square foot of surface, therefore, sustained $229 \div 172 = 1.33$ lbs.

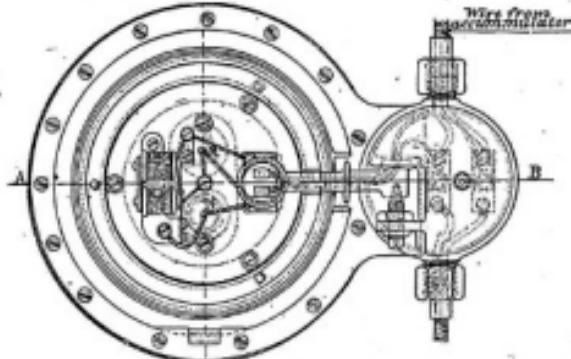
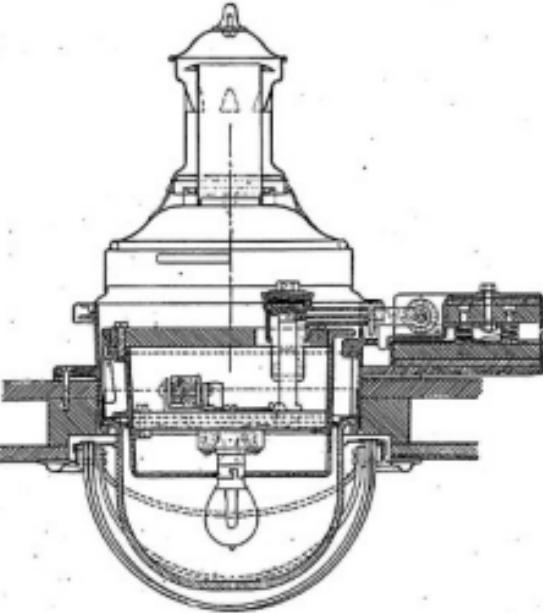
The up thrust of the wind (the lift) upon the wing surface is perhaps half as much as the pressure of the same wind upon the same surface if turned perpendicular thereto.¹ Now, as the apparatus therefore needs to sustain it a wind producing a pressure of $1.33 \times 3 = 3.99$ lbs. per square foot, we see that (by ordinary tables of wind pressures) it must blow at a velocity of about 23 miles per hour.

I have, however, been very cautious about exposing myself to such a wind with this large apparatus; and in such high winds have used smaller surfaces for my sailing practice.

This year I selected a locality between Steglitz and Schönebeck.

It had, however, the disadvantage that only westerly starts were possible. Herr Kassner has again taken instantaneous photographs of my apparatus, which have been laid before the society (fig. 74). The strongest winds in which I practised had a velocity which I estimated at between 15 and 18 miles per hour. By running I obtained an additional velocity of 7 miles an hour, making the total relative velocity 22 miles an hour, which was required for soaring. Under these circumstances the first part of my flight was almost horizontal, and the alighting was always a gentle one. . . . Each apparatus had a vertical and horizontal tail, without which it is impracticable to practise in the wind. In conclusion, I will remark that sailing flight near the earth's surface must be much more difficult than at greater heights, where the wind blows more regularly, while every irregularity of the ground at lower levels starts whirls in the air.

(TO BE CONTINUED.)



ELECTRIC LAMP, PARIS, LYONS & MEDITERRANEAN RAILWAY.

ELECTRIC LIGHTING ON THE TRAINS OF THE PARIS, LYONS & MEDITERRANEAN RAILWAY.

In our issue for March we gave a short description of the method of electric car lighting in use on the Northern Railway of France, supplementing the same in our April issue by a description of the system in use on the Paris-Simplon Railway.

¹ Lillenthal, "Der Vogel als Grundlage der Fliegekunst," Tafel VII.

needed to be given in order to overcome the practical difficulties in imitating the birds. Those points related to a better adjustment of the center of gravity, to methods for obtaining greater stability, and to the mode of management of the apparatus when the wind blew more rapidly than 11 to 13 miles per hour.

In the issue of the *Zeitschrift für Luftschifffahrt* for November, 1892, Herr Lillienthal published an article on "Soaring and its imitation," in which he gives a brief account of his experiments in the summer of 1892, from which the following abstract has been prepared:

Many theories have been proposed to explain soaring. My own explanation is based upon the advantageous relations of air resistance incident to the use of slightly curved wing surfaces (as I have demonstrated) and upon the gently rising trend of air current which I have found to prevail.

A flying apparatus which has the same proportions as those of a good soaring bird and is of sufficient size to carry a man can scarcely be held fast by three or four men together when exposed to a brisk wind. When we look at the safe and quiet sailing of the birds it almost seems as if some undiscovered mechanical principle were at work, some feature in the elastic properties of air or in the classic curvature of the feathers which accounts for the mystery of soaring flight; but my experiments have taught me that there is no mystery, and that the same mechanical science which has explained the theory of the steam-engine and followed the orbits of the planets is adequate to explaining the operations of soaring flight.

Dexterity alone, in my opinion, invests the native inhabitants of the air with superiority over man in that element. . . . Inasmuch as continuous soaring with large wings in high winds can terminate in scarcely anything but the destruction of the foolhardy fellow who may first attempt the experiment without previous practice, I first undertook last year to gain some experience with a smaller apparatus and in moderate winds. In spite of my caution the wind several times played the mischief with me. Even with only 96 sq. ft. of sustaining surface, I was several times tossed up into the air by unexpected gusts of wind, and but for the circumstance that I was able to release myself quickly from my apparatus, I might have had a broken neck instead of the sprains in feet or arms which always healed in a few weeks.

Almost every Sunday, and sometimes on week days, I went out to practice on the hill between Grosskreutz and Werder. A mechanist, Herr Hugo Eulitz, the maker of my apparatus, went with me, and each practised alternately while the other rested. Thus we obtained dexterity in gliding down on the air and in landing at the foot of the hill without mishap.

Herr Kassner, of the Meteorological Institute, was so kind as to photograph me in the air, and has thus enabled me to exhibit to the members of the society how I sailed right over the head of the miller of Derwitz (in whose barn I stored my apparatus) and of his esteemed poodle dog.

Equipped with the experience gained in 1891, I this year attempted to soar with wings measuring 172 sq. ft. in surface. My apparatus weighed 53 lbs., and my own weight is 176 lbs., so that the whole was 230 lbs. Each square foot of surface, therefore, sustained $230 \div 172 = 1.33$ lbs.

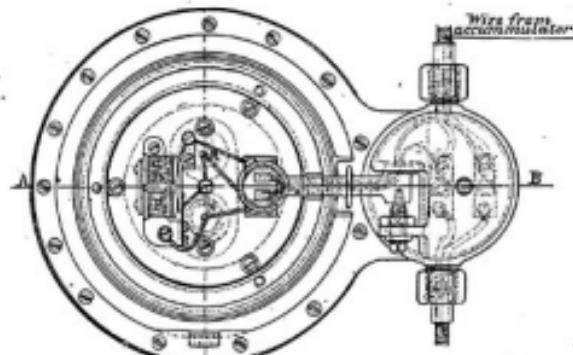
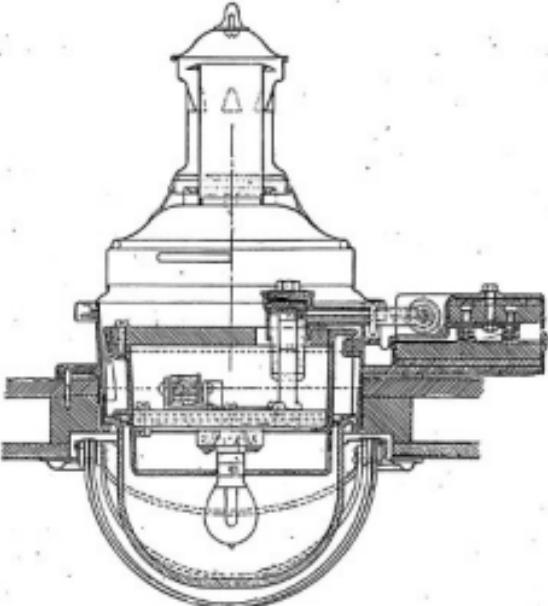
The up thrust of the wind (the lift) upon the wing surface is perhaps half as much as the pressure of the same wind upon the same surface if turned perpendicular thereto.* Now, as the apparatus therefore needs to sustain a wind producing pressure of $1.33 \times 2 = 2.66$ lbs per square foot, we see that (by ordinary tables of wind pressures) it must blow at a velocity of about 23 miles per hour.

I have, however, been very cautious about exposing myself to such a wind with this large apparatus; and in such high winds have used smaller surfaces for my sailing practice.

This year I selected a locality between Steglitz and Schöne.

It had, however, the disadvantage that only westerly winds were possible. Herr Kassner has again taken instantaneous photographs of my apparatus, which have been laid before the society (fig. 74). The strongest wind in which I practised had a velocity which I estimated at between 15 and 16 miles per hour. By running I obtained an additional velocity of 7 miles an hour, making the total relative velocity 23 miles an hour, which was required for soaring. Under these circumstances the first part of my flight was almost horizontal, and the alighting was always a gentle one. . . . Each apparatus had a vertical and horizontal tail, without which it is impracticable to practise in the wind. In conclusion, I will remark that sailing flight near the earth's surface must be much more difficult than at greater heights, where the wind blows more regularly, while every irregularity of the ground at lower levels starts whirls in the air.

(TO BE CONTINUED.)



ELECTRIC LAMP, PARIS, LYONS & MEDITERRANEAN RAILWAY.

ELECTRIC LIGHTING ON THE TRAINS OF THE PARIS, LYONS & MEDITERRANEAN RAILWAY.

In our issue for March we gave a short description of the method of electric car lighting in use on the Northern Railway of France, supplementing the same in our April issue by a description of the system in use on the Jura-Simplon Railway.

* Lillienthal, "Der Vogelflug als Grundlage der Fliegekunst," Teil VII.