upon to stoke, the results attained cannot be considered otherwise than highly satisfactory, it being asserted by some critics, who consider themselves entitled to be judges in such matters, that it is the contractor-trained stokers alone who can obtain good results on such trials, results, they say, which are never repeated by navy stokers.—*The Engineer, London.*

THE SOLUTION OF THE FLIGHT PROBLEM.*

By KARL BUTTENSTEDT.

IT was calculated by Babinet, at the beginning of this century, and, of course, on approved mathematical data, that for purposes of flight a man would require about twenty-five times as much power as he possesses; and now, at the close of the century, the

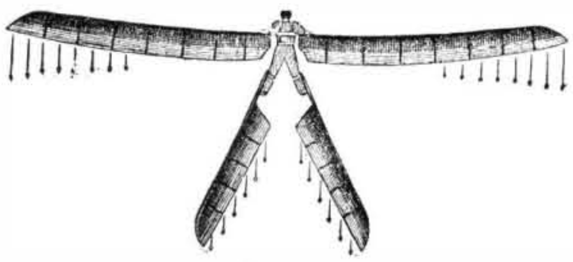

FIG. 1.

mathematician Parseval calculates that, approximately, eight horse power would be required. These "infallible" calculations by the scientists have been the real hindrances to practical effort. I ask any thinking observer of nature, who has watched the slowly upward-circling stork, which ascends without any appreciable wing motion, whether the bird gives him the impression of expending any such force (relatively to his weight) in flight? If not, what aid may we expect from a scientific theory which does not conform to the actual facts?

As Eugen Kresz shrewdly remarks: "We possess in the science of flight technics a stately theoretical structure, but, unfortunately, without any sure foundation, so that it is to be feared that, with the practical solution of the problem, the proud theoretical structure will fall to pieces." There are purely practical, elementary problems, sublime beyond all bold-soaring theories. Such an elementary problem is the problem

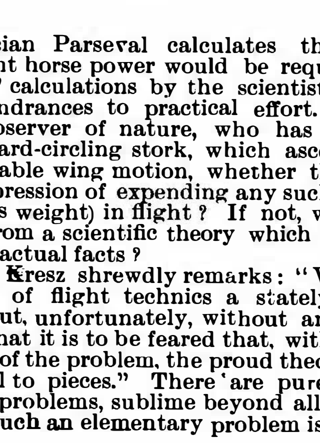

FIG. 2.

of flight, which presents itself to the observing eye as one of the most simple, mechanical, physical acts of winged creatures. And what a complicated, confused caricature has theory made of this simple phenomenon!

That extraordinary vehicle, the bicycle, was, for example, discovered without mathematics, without theories, and what a splendid achievement it now is!

This affords an instance of what a man can do with his one-seventh horse power when he is put to it; and it is another good sign for the solution of the flight problem, that specialists like Lilienthal, Kresz, von Miller-Hauenfels, Kreisz, Mewes, Bosse, Milla and others, hold opinions entirely opposed to those of Parseval, and believe that man is capable of flight by his own unaided strength. "Late experiments teach us," says Lilienthal, in vol. 5 of the *Zeitschrift fur Luftschiffahrt*, 1893, "that light and strong motors might be utilized, but that the problem of aerial navigation does

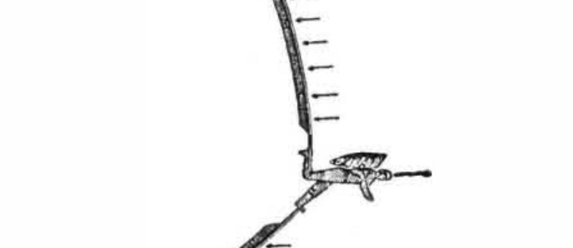

FIG. 3.

not depend on them;" and this remark indicates clearly that this tangled problem is in a fair way of being unraveled. Now that we really begin to apprehend the merits of the problem, we are in a fair way of accomplishing its solution. Hargraves' model, by means of 42 strokes of its little elastic wings, made a horizontal flight of 146 meters, and Lilienthal himself flew 80 meters against a strong wind, several times resting, for seconds, in the air, after springing to a height of 10 meters. Engineer Koch also succeeded in flying a short distance, and Professor Langley's model rose by means of two screws.

It is, hence, evident that we have at length found the clew that will guide us out of this labyrinth of confusion. What is now needed is to define clearly the simplest essentials of individual flight. That achieved, there will be no difficulty in constructing apparatus for the transport of two, five or a hundred persons. The task must be accomplished gradually, as the bird learns to fly. Nature does not advance *per saltum*.

*Translated and condensed for the *Literary Digest* from a paper in *Der Stein der Weisen*, Vienna, Heft 21.

As the greatest mechanical discoveries rest on the co-operation of a sum of trifles, so the whole problem of bird flight rests on a trifle, that is, on the pressure of the atmosphere on a suitable oblique surface. The most suitable would be, as in the case of the bird's wings, of elastic quill feathers. The end portion of such a surface is made as follows: To a tube, elastic feathers wrapped in some woven material are attached. In a condition of rest the tube or bamboo lies as in the design, Fig. 1. By beating the air, as in a wing stroke, the elastic surface, under the influence of the wind, adjusts itself obliquely to the direction of the stroke, in the same manner as the wings of a windmill stand obliquely to the direction of the wind. But, since, in the flying machine, we hold the tube firmly in the hand, it bends toward the right, and the column of air underneath the oblique surface is thrown, ray-like, to the left. The resistance which this radiating air opposes to the movement of the wings is the same force which presses their oblique surface to the right. The measure of this force is precisely the same as the elasticity of the bamboo or tube. The tube registers exactly the force of the stroke, and, thereby, also the strength of the atmospheric pressure, in the form of the translation of the force of the stroke into force of elastic tension. The stronger the stroke and the movement of the surface against the atmospheric pressure, the stronger is the elastic curvature of the tube. This bending of the tube results, whether we move the surface against the wind, or hold the surface still and let the wind blow against it, as in a sailing ship or a windmill. Just conceive for yourself, as in Fig. 1, a man suspended under two light, elastic, windmill wings, made of a bamboo with quill feathers attached. The man springs like a condor from an eminence. Suppose there were no wind, the man begins to move downward, but the surface of the wings, under which he hangs, meets a pressure from below. It is precisely the same as if there were an atmospheric pressure from below, upward. The consequence is that the points of the wings bend upward; and now, in the same manner, the air underneath rushes backward; for this falling is really a soft stroke movement. The wing surfaces are expanded horizontally, because the heavy body of the man cannot be so easily arrested in its falling movement as the rapidly moving wing points demand. If the man is heavier than the average, the initial falling movement is quicker, the corresponding atmospheric pressure proportionately stronger, and, consequently, the tension, also. But, the tension is the equivalent of the sailing power and, the conditions being equal, a heavier body will sail more rapidly than a lighter body. With such wings, it would be impossible to fall perpendicularly; the body would glide forward like a sailboat; and, in the case of a bird, to such an extent that it can sail almost horizontally without an effort. It cannot pause in its flight, its force of gravitation would at once carry it downward; this would generate atmospheric pressure upward, which would again waft it on its way.

As accessories to the sailing wings, the aeronaut will require a pair of smaller leg sails, with which he can both propel and steer himself. These can be practically operated like a screw, as in Fig. 3. It need not be supposed that this extension and operation of the wings and arms is in any sense exhausting. On the contrary, the sailing surfaces are always opposed to the point from which the wind blows, and the legs, instead of having to support the flying attachments, will be supported by them.

To solve the riddle of bird flight in a few words, it is, in my view, nothing but the translation of the force of gravity into sailing power. In this translation, nothing is lost beyond what is due to the friction of the air. When this trifling loss of power, due to friction, is compensated by an equivalent of the aeronaut's force, the whole force of gravitation can be transposed into floating power, and we can maintain our flight for an indefinite period. The aeronaut has in the weight of his own body a powerful motor for flight, and requires the exercise of but little power to maintain him in motion; he could certainly sustain the exercise as long as a wheelman could keep going. But that he would travel much faster than the wheelman is beyond all question.

THE SECOND TRACK OF THE ST. GOTHARD RAILROAD.

IN May, 1893, the second track of the St. Gothard Railroad was opened for traffic. The following account of its construction is abstracted from a recent paper by the chief engineer of the railroad, Mr. Schrafl, in the *Schweizerische Bauzeitung*. To convey an idea of difficulties encountered in this work, we give a short description of the first track of the St. Gothard Railroad.

A treaty betweeen the three states, Germany, Switzerland and Italy, that are most interested, was made in 1871 to aid the building of a St. Gothard railroad by actual payments of the cost and by guarantees of interest. The construction was then commenced on the basis of several surveys begun in 1856. The railroad was completed in 1882. The great St. Gothard tunnel, being the most important work, had been first located. Its highest point is 3,785 ft. above sea level, and the respective elevations of the initial and terminal ends are 1,365 ft. and 700 ft. The ascent on the northern side is made through the Reuss Valley and on the southern side through the Tessin Valley. Neither of the valleys has cross valleys which could be made available for the development of the railroad line; they are inclosed by high and precipitous mountains which have an average slope of 30 deg. to 45 deg. The mountains consist of hard gneissic granite, in which are embedded softer strata of micaceous schist, of mica slate and of slate and limestone.

The total length of the St. Gothard Railroad is 159 miles, and the line may be divided into five distinct divisions, the two valley lines, the two mountain lines or ramps, and the great tunnel itself. The northern ramp commences at Erstfeld at an elevation of 1,520 ft. above sea level, and extends to Goeschenen, 3,645 ft. high, to the northern entrance of the Gothard tunnel, a distance of 12·25 miles. The fall of the valley varies from 63 ft. to 285 ft. per mile. The tunnel ends at Airolo in the Canton Tessin at an elevation of 3,755 ft. from where the road descends the valley of the Tessin to Biasca, a distance of 21·6 miles. The difference in elevation between these two points is 2,750 ft., and the fall of the Tessin ranges between 53 ft. and 550 ft. per mile. The prime factor in the location was to follow the natural grade of the valley as long and as near to its bottom as possible and to accomplish the ascent at a few points, where there were breaks in the slope of the valley. This was done by building spiral raising tunnels, of which there are three on the northern and four on the southern ramp. The grade in the spiral tunnels is 121 ft. per mile, whereas the maximum grade otherwise was fixed at 137 ft.

The approaches Erstfeld-Goeschenen and Airolo-Biasca had originally been built for single track, but wherever the future double tracking would have been impossible after the opening of the traffic, or would have entailed considerable extra expenses, provision had been made for two tracks. For the tunnels the Pressel-Kaufmann sections were chosen, as they admit of enlargment for a second track, as shown by the illustrations, Figs. 1 and 2. A number of retaining walls

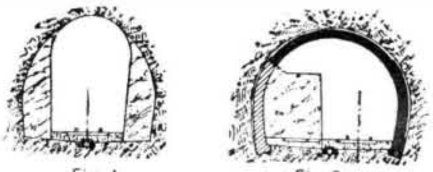

Fig. 1. Fig. 2.

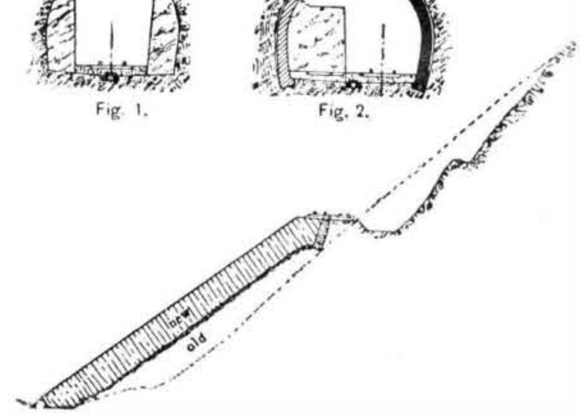

FIG. 3.

and the pier and abutment foundations of the larger bridges had been built for two tracks except where the masonry rested directly on rock. The great tunnel and four smaller ones had been arranged for double track when built. The rapid growth of the traffic of the road required the building of the second track, and in October, 1887, it was commenced, with the expectation of completing it in 1896. The continual increase of traffic made it desirable to shorten the time of construction, and the work was pushed so successfully that the second track was opened in May last.

In building the first track some definite assumptions had been made about the location of the second track, but the elaboration of detailed plans for the latter necessitated frequent deviations for reasons of economy, better acquaintance with the locality and avoidance of dangerous building operations; so that though the two tracks are parallel, in general they cross each other repeatedly. This rendered it necessary to discontinue and shift parts of the superstructure. Sometimes the roadbed was enlarged on both sides and the axis of the double track road changed accordingly. The minimum distance between centers of tracks was fixed at 11·5 ft., which is exceeded at the stations and other places. The work upon the substructure was let in short sections, to have the contractors give their personal attention to all work. Freight cars for the transport of materials, rails, fastenings, transfer and turn-

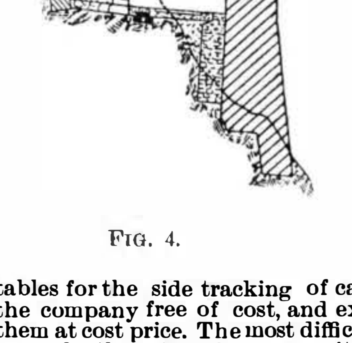

FIG. 4.

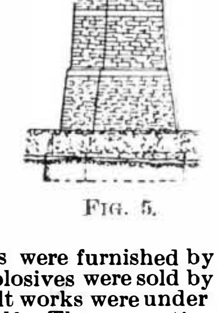

FIG. 5.

tables for the side tracking of cars were furnished by the company free of cost, and explosives were sold by them at cost price. The most difficult works were under taken by the railroad company itself. The excavation and transport of earth and rock on the open road comprised 690,000 cu. yds. A number of high embankments on the southern approach had to be widened, and to do this work over 100,000 cu. yds. were brought down at night from Airolo, where they had been deposited during the excavation of the great tunnel. Fig. 3 shows one of these embankments, 85 ft. high. At various other embankments it was preferred to enlarge the roadbed by building dry walls at batten of 1:3 and 1:2. Of the 30 tunnels on both the ramps, only four small ones, of a total length of 930 ft., had been originally built for double track; of the others, 38,500 lin. ft. had to be enlarged and partly lined; 243,000 cu. yd. of work were excavated and 38,000 cu. yd. of masonry were built. The tunnel work was done almost exclusively at night, because the train intervals were longest then, and the smoke least bothersome. The excavated material was removed on low platform cars