This service costs $13.50 per week; $12 for the plates, and $1.50 for a week's expressage. Many head printers "make up" these plates as neatly as could be done with type, and while no pressman can disguise the fact that his is a "plate" paper, the reader does not seem to remark the difference. Five years ago there were many sneering remarks about this sort of matter, and it was claimed that the line between city and country papers could be drawn at "plates," but some very creditable morning papers now use them. The use of plates is an old newspaper principle. A paper that costs thousands of dollars to produce is sold for a penny, and the paper sold at this low price, in spite of the enormous original cost, is read by at least four persons who pay nothing at all for it. The reader in California does not find his paper less interesting because a copy of the same printing is being enjoyed also in New York. It costs several hundred dollars to produce six columns of the best plates; yet a country publisher may buy stereotype duplicates of the six columns for two dollars. And the matter is not less interesting to his readers because many other publishers in many other States are using the same articles. The surprise is that, although stereotyping is an old process, stereotype plates have only been generally used eight or ten years. I sometimes doubt that ready-printed sheets have been of any great service to country newspapers, but the invention of plates was a long stride forward. By their use country newspapers may secure at small expense the services of the very best writers; by their use every country publisher may secure a great staff of special writers and artists. Every field except the local field is covered by the plates, and it is almost certain that the service will steadily improve.

E. W. Howe.

THE POSSIBILITY OF MECHANICAL FLIGHT.

BY THE SECRETARY OF THE SMITHSONIAN INSTITUTION.

THE publication by the press of a memoir I lately read to the National Academy of Sciences on the power required for mechanical flight has caused so much misapprehension, but also so much interest and inquiry, that I willingly accept the invitation of THE CENTURY to give here at least such an explanation as consists with the imperfection of a brief account in untechnical terms.[1]

In the first place, let me explain that I have in no way said that man can fly by his own strength, nor have I ever described the details of any particular "flying-machine." What has been done is to demonstrate by actual experiment that we have now acquired the mechanical power to sustain in the air (and at great speeds) bodies thousands of times heavier than the air itself, and that as soon as we have the skill to direct this power we shall be able actually to fly.

As the distinction between the possession of sufficient mechanical power and the skill to use it may not be clear, let us observe that an ordinary balloon is essentially lighter than the air and will float in it, moving only with it, at the mercy of the wind, like a log in moving water; while the flying-machine of the future that we now speak of is to be heavier than the air, and, being designed to glide on it somewhat like a skater on thin ice, will sink if it has not power to keep moving rapidly enough to make the air support it.

It seems at first incredible that any practically obtainable power can make the viewless air at the same time support a dense body like brass or steel, and cause it to run rapidly and securely along upon the thin element. Nevertheless I have seen it done; and for this best of reasons it has seemed to me that it can be done again, and that such a matter as mechanical flight ought not to be left to the opprobrium which past mistaken efforts and consequent failure have brought on it, but that it should be reinvestigated by scientific methods.

The distinctive mark of such methods is the primary importance attached in them to obtaining definite ideas about quantity, in order to state everything in number, weight, and measure, so that we may be able to prove, for instance, just how much power is demanded for such aërial transport, and if this be beyond the ability of a man's muscles to furnish, to prove definitely whether we can or cannot build an

[1] For fuller and exacter statement the reader is referred to a recent publication by the Smithsonian Institution, "Experiments in Aërodynamics."

engine at once strong and light enough to supply this power. Almost all notions about the capacity of the air for this kind of support have been and are very vague, and are in complete contrast to the precise ones science possesses on other matters. It is to furnish these exact data, it is to answer with certainty the question "How much?" that these new experiments have been made; and few things can, it seems to me, be of more interest than their results.

Above us is the great aërial ocean, stretching over all lands, and offering an always open way to them, yet a way that has never yet been thus trodden. Can it be that the power we have always lacked is at last found, and that it only remains to learn to guide it?

Let me, in answering, compare the case to that which would present itself if the actual ocean had never been traversed because it was always covered with fields of thin ice, which gave way under the foot, which indeed permitted vessels to be launched and to float, but which compelled them to move wherever the ice drifted. Such vessels would resemble our balloons, and be of as little practical use; but now suppose we are told, "The ice which has always been your obstacle may be made your very means of transport, for you can glide over the thinnest ice, provided you only glide fast enough, and experiments will prove not only how fast you must go to make the ice bear, but that it is quite within the limits of your strength to go with the requisite speed." All this might be true, and yet if no one had ever learned to skate, every trial of this really excellent plan would probably end in disaster, as all past efforts to fly have done. Indeed, in our actual experience with the air, men have come to the same kind of wrong conclusion as would have been reached in supposing that the ice could not be traversed because no one had the strength to skate, while the truth would be that man has plenty of strength to skate, but is not born with the skill.

The simile is defective so far as it suggests that man can sustain himself by his unaided strength on calm air, which I believe to be impracticable; but it is the object of these experiments to prove that he has now the power to sustain himself with the aid of engines recently constructed, and by means I indicate, as soon as he has skill to direct them.

All the time which I have been able to give to the subject during the past four years has been spent in continuous experiment in order to determine exactly how much power is required, and how it should be applied, to sustain in rapid motion quite dense bodies in the shape of plates or planes (somewhat as a skater is sustained on thin ice), by distributing their weight over a great mass of air, whose inertia prevents it from getting out of the way, owing to the swiftness with which they can be made to glide over it.

The experiments were made with the aid of a steam-engine of ten horse-power, which put in horizontal motion a long arm at the end of which a great variety of specially devised apparatus was connected with such planes, which were made to advance with exactly measured speeds up to seventy miles an hour.

Beginning with the year 1887, many thousand experiments of this and many other kinds were made, of which only the general result can be stated here. In one class of these trials the plane was attached to a dynamometer, which showed, in connection with a chronograph, the amount of power which made the air just support the plane, so that it neither rose nor fell, but soared along horizontally; while among the first results of observation was a demonstration of the important fact that it takes less power to sustain such a body in horizontal motion than when it is suspended over one place — a conclusion the very reverse of that formerly reached by physicists, who, not having tried the actual experiment, started from the plausible assumption that we must first see how much power it will take to keep the body suspended over one spot, and then add to that power something very much larger to find what it requires both to suspend it and to move it along.

To mention a single experiment out of many bearing on this last point, a sheet of brass in the form of a plane was suspended from the horizontal arm by a spring-balance, which, when all was at rest, was drawn out to a distance corresponding to the weight. As soon as the arm was put in movement, however, and lateral motion began and increased, the spring (which now not only sustained the plane but pulled it along) *contracted* more and more instead of lengthening, showing that the pull diminished with each increment of speed and each corresponding diminution of the inclination. It is very interesting to see with what slight power the heavy metal, when in such rapid motion, can be made almost to float on the air, and one can be convinced by the evidence of the spring-balance or the dynamometer, combined with the record of the speed, that (within the limits of experiment) it requires less and less power to maintain this horizontal transport of the plane the faster it goes. The above experiment is given only as an illustration, but the important conclusion just mentioned was not accepted till it had been confirmed by hundreds of varied demonstrations.

In another class of experiment the plane is no longer attached to the balance, but is placed horizontally, and left free to fall through a constant small distance while keeping in that horizontal position, but at the same time being urged forward. Since it is not inclined either way, or, as a physicist would say, since there is no visible component of pressure to increase or diminish the time of fall, this time might be supposed to be the same whether it were dropped from a position of rest, or in such motion. Actual trial, however, shows the contrary in a very striking manner, for a plate more than a thousand times denser than the air may under such conditions be seen to settle down with an extraordinary slowness, as if it had almost parted with its weight, or, rather, as if the air had hardened under it into a jelly-like condition. The fact established here is also an important one, for it shows not only that by moving fast enough on it, air can be made to offer support like an elastic semi-solid, but, taken in connection with other experiments, it elucidates the result already referred to, and which, in view both of its importance, and of what may perhaps appear to the professional reader its paradoxical appearance, I will (to leave no doubt about my meaning) ask permission to repeat here in carefully chosen language. This general result is that "if in such aërial motion there be given a plane of fixed size and weight, inclined at such angles and moved forward at such speeds that it shall always be just sustained in horizontal flight, then the more the speed is increased the less will be the power required to support and advance it, so that there will be an increasing economy of power with each higher speed, up to some remote limit not yet attained in experiment." This is in startling contrast to all that we are most familiar with in land and water transport, where every one knows the direct reverse to be the ordinary case.

A mechanism designed to secure artificial flight by thus taking advantage of the inertia and elasticity of the air I call an aërodrome (air runner). In order to give a specific example of the weights and speed actually tried, I will select one out of many hundred experiments. This showed that one horse-power could transport and sustain in such horizontal flight over two hundred pounds' weight of loaded planes at the rate of fifty miles an hour; by which is meant that such planes actually did rise up from their support, under the reaction of the air at this speed, while carrying weights in this proportion to the horse-power, and soared along under all the circumstances of actual free flight, except that they were constrained to fly horizontally.

Engines have very lately been made for a special purpose, to weigh, together with a supply of fuel for a short flight, considerably less than twenty pounds to the horse-power, everything movable included. Again, less than twenty pounds is actually necessary for the weight of a system of planes strong enough to support the engine and accessories; so that less than forty pounds being sufficient for such power and support, while two hundred pounds can be carried, a wide margin remains for contingencies.

Now planes have only been used for the convenience of getting exactly comparable and verifiable values, and as other forms of surface will probably give better results in practice, there is reason to believe that still more weight than that here given can be transported at this speed by one horse-power — that is, in level flight.

The aërial journey in fact is in this respect somewhat like a terrestrial one, where the traveler can ride over a nearly straight and level path to his destination if he can but control his steed; which, if it ran away with him, over mountains and valleys, would be behaving like an aërodrome having sufficient power for proper flight, yet which, if not guided into such flight, would be wasting this power in aimless efforts.

These experiments also indicate in general what difficulties are to be avoided to secure such guiding, but the memoir confines itself mainly to showing the principles on which machines can be built, which will demonstrably fly with the power now at command if we can but thus guide it. The present memoir does not undertake to teach in detail how to steer a horizontal course, how to descend in safety, or the like,— all very important matters, but subordinate to the main demonstration.

If asked whether this method of flight will soon be put in practice, I should have to repeat that what has preceded is matter of demonstration, but that this is matter of opinion. Expressing, then, a personal opinion only, I should answer, "Yes." It is hardly possible that these secondary difficulties will not be soon conquered by the skill of our inventors and engineers, whose attention is already beginning to be drawn to the fact that here is a new field open to them, and though I have not experimented far enough to say that the relations of power to weight here established for small machines will hold for indefinitely large ones, it is certain they do so hold, at any rate far enough to enable us to transport, at speeds which make us practically independent of the wind, weights much greater than that of a man. Progress is rapid now, especially in invention, and it is possible — it seems to me even probable — that before the century closes we shall see this universal road of the all-embracing air, which recognizes none of man's boundaries, traveled in every direction, with an effect on some of the conditions of our existence which will mark this among all the wonders the century has seen.

S. P. Langley.