AEROPLANE EFFICIENCY.*

EFFICIENCY in an aeroplane, as in any other machine, is the determining factor in its capacity to do big work on a limited supply of fuel. Long journeys and flights of extended duration are limited by this, quite apart from any consideration as to the stability of the machine, the skill of the pilot, or the behaviour of the weather.

From land to land across the Atlantic Ocean, the shortest distance is some 1,700 miles, which would occupy about 28 hours on a machine averaging 60 miles an hour. Fuel is being consumed during the whole of this time at a minimum rate of ·65 pints of petrol per horse-power hour, whence at least (28 × ·65 = 18·2) pints would be needed for every horse-power developed by the engine employed. This quantity would weigh, for petrol of ·7 specific gravity, approximately 15 lbs.

In flight, an engine works at full power all the time, so there is no discount on the above figure when it is multiplied by the power of the engine in order to obtain the total quantity of fuel consumed.

The engine itself would weigh at least 3 lbs. per horse-power, whence the power plant alone represents (15 + 3 = 18 lbs.) per horse-power as a minimum for the journey. The engine that would carry itself across the Atlantic must therefore, be capable of supporting 18 lbs., in flight at 60 miles per hour, per horse-power developed.

One horse-power is equivalent to 6·3 lbs. thrust at 60 miles per hour, and the ratio 6·3 to 18 = ·35, represents the minimum thrust-lift ratio, "efficiency," or, as I prefer to call it, "coefficient of flight," for this imaginary system in which the power-plant is supposed to be flying without wings or propeller.

Directly the aeroplane and pilot are introduced into the calculation, this minimum value is altered considerably, for however light you may conceive it possible to build a machine, the man, at any rate, will weigh 150 lbs. if he is a normal specimen of humanity. This weight and the weight of the machine are fixed quantities, and their influence on the efficiency factor is greater the smaller the engine, for the more powerful the motor the less per horse-power is the increment that they represent.

For example, suppose the aeroplane and the pilot weigh 1,000 lbs. while the engine is 100-h.p.; their increment represents 10 lbs. per horse-power to the absolute minimum of 18 lbs. per horse-power in flight at 60 miles per hour, and thereby alters the coefficient of flight to ·225.

Alternatively, if only 50-h.p. is employed, the efficiency ratio is raised to 38 lbs. per horse-power, which is equivalent to a coefficient of flight of ·166. Thus, the less powerful the engine the more efficient must be the aeroplane as a whole, consequently *the chances* of building a machine that will do the job *increase with the power* of the engine, provided always that such an engine is itself as economical and light per horse-power as one of lower power.

The extra total weight of fuel required for the larger engine only effects the question in so far as it may adversely influence the design of the aeroplane proper, on which, of course, it must be carried. So far as it represents dead weight, it is proportional to the power developed, and, therefore, it is immaterial whether there is much of it or little.

If there is a difference in fuel economy between one engine and another, the length of the journey determines whether this difference is important or not, for the effective difference in weight per horse-power brought about thereby is ascertained by multiplying the difference in the rate of fuel consumption by *time*.

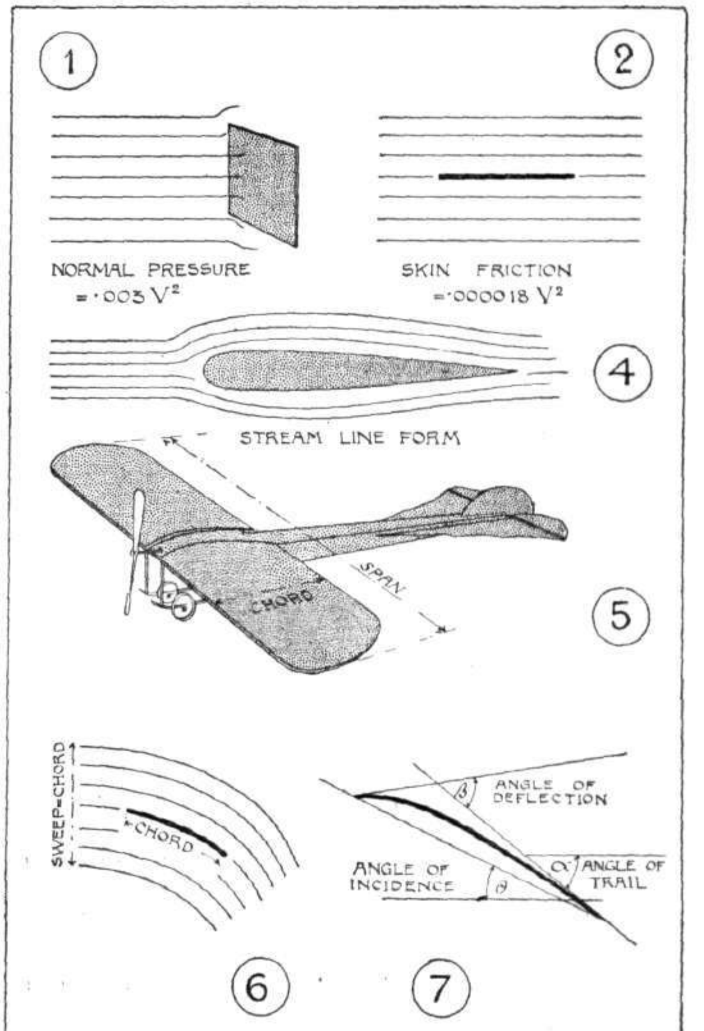
If, on the other hand, the difference between two engines is solely one of weight per horse-power, then the effective importance is uninfluenced by the nature of the flight. Also it is generally small by comparison with the increment represented by the weight of the aeroplane and pilot, as explained above. For example, if the engine weighed 4 lbs. per horse-power, instead of 3 lbs. per horse-power, this would only mean a difference of 1 lb. per horse-power, whereas the aeroplane and pilot represent an increment of at least 5 lbs. per horse-power with a 100-h.p. engine.

For the sake of argument, let us assume that the engine develops 100-h.p. and works under the above conditions. It will require (100 × 15 = 1,500) lbs. of fuel for the journey. This quantity of petrol would occupy (at 43·4 lbs. per cubic foot) nearly 35 cubic feet, and could be carried in a cylindrical tank 2·5 ft. in diameter by 7 ft. long. This investigation is important; it shows whether it is practicable to carry the initial quantity of fuel that must be put on board before the start of a long flight. Also it is some indication as to the strength and size of the aeroplane that would be required to carry the fuel in addition to the pilot and any other extra load.

It should interest those who have not previously studied this aspect of flight to observe that some fairly tangible conception of the problem is afforded by such a simple application of first principles in mechanics. None of the above deductions have been founded on any special knowledge of the laws of flight; it is simply and purely an armchair analysis of the fundamental situation, for all that has been done is to say what the coefficient of flight must be if a certain weight is to be sustained at a certain speed by a certain power.

As the conception of a self-supported mass in continuous horizontal motion is not elsewhere presented by any ordinary problem in mechanical science, it often happens that even the trained mind fails to appreciate this fundamental simplicity of the case. When a definite weight is known to be supported in horizontal motion at a definite speed by the exertion of an engine of definite power, then these very data themselves establish the ratio of thrust to lift that is the measure of an aeroplane's "efficiency," which I have otherwise expressed by the more appropriate term "coefficient of flight."

To know that a certain coefficient of flight is obtainable is one thing, to know how to obtain it is another. Investigation of this side of the question leads on to a study of resistance to motion through the air and the lift of a wing in flight.



* Paper read by A. E. Berriman, Technical Editor of FLIGHT, before the Royal Society of Arts, on November 29th, 1911.