THE VOL PIQUÉ.

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[FOLLOWING upon a request made at the time of the last Olympia Show, Mr. J. H. Hume-Rothery has been devoting a great deal of his time to the mathematical investigation of the conditions represented by the forced dive as a consequence of being partially stalled in the air. The question as to the least height in which it is possible to recover horizontal flight after being stalled is a matter of first-class importance to pilots, for there is evidence that more than one accident has happened as a consequence of being unable to flatten out in the height available. We trust, therefore, that Mr. Hume-Rothery's article, which represents infinitely more labour than is apparent from the abbreviated and simplified form in which he presents his conclusions, will be read with the interest and appreciation that it deserves.—ED.]

IF an aeroplane loses its velocity relative to the air in which it is flying, the air pressure on its wings is then insufficient to support its weight, and it begins to descend. If this loss of velocity is considerable, the descent will be a more or less headlong dive—a *vol piqué*—in which, like any other falling body, the aeroplane will regain speed. This loss of velocity may be due to the pilot's attempting to climb too steeply, and so bringing the aeroplane almost to a standstill, but it may also be due to causes quite beyond his control, such as sudden changes in the strength of the wind. While ordinary gusts are of very short duration, it is pointed out on p. 217 of the Technical Report of the Advisory Committee on Aeronautics for 1911-12, that not infrequently gusts occur which last for one minute or even longer. If an aeroplane is flying down-wind during such an increase of wind velocity, or flying up-wind during a sudden lull, it experiences a sudden loss of relative velocity, and a dive must follow.

The most important point in practice is to know how great a vertical fall the aeroplane must undergo before it can regain its normal speed and horizontal direction of flight, as if it reaches the ground before this an accident will probably occur. A knowledge of this matter then will help us to form an estimate of the minimum height above the earth at which it is safe to fly.

In order to calculate this, it is necessary to know exactly the air pressures on the aeroplane at all velocities and angles of incidence. The above-mentioned Technical Report gives these very fully on p. 112 for the aeroplane BE 2, and consequently I have adopted this aeroplane and the data given for the purpose of the following calculations, and the results obtained may be taken as typical of all aeroplanes. From the diagram opposite p. 112, I have calculated and plotted on a chart the lift and total resistance in lbs. for all angles of incidence from 2° to $12\frac{1}{2}^\circ$, at a velocity of 1 ft. per sec. per lb mass of aeroplane, so that to get the actual lift and drift, one must multiply by V^2 (in ft. per sec.), and by the mass of the aeroplane (1,530 lbs.).

If V = velocity of aeroplane in feet per sec.,

ϕ = inclination of its path below the horizontal,

α = angle between the chord of wings and direction of motion,

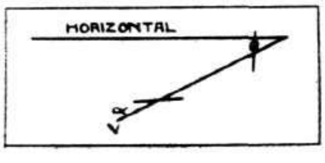
then the equations of motion are

$$\frac{dV}{dt} = g\,\frac{\text{thrust}}{\text{mass}} + g\sin\phi - g\left(\frac{\text{drift in lbs.}}{\text{mass}}\right)$$

$$\frac{d\phi}{dt} = \frac{g\cos\phi}{V} - \frac{g}{V}\left(\frac{\text{lift in lbs.}}{\text{mass}}\right)$$

This method, using V and ϕ, has proved much more convenient than attempting to use the horizontal and vertical components of motion. When the values of V and ϕ have been calculated at regular intervals of time the course of the aeroplane can be easily plotted.

The aeroplane BE 2 flies normally at about 3° incidence, which corresponds to a velocity of 91·6 ft. per sec., and in the following calculations I have assumed its velocity initially reduced to 50 ft. per sec. This would be caused by a gust of 41·6 ft. per sec., or about 28 m.p.h. Since the gusts given on the above-mentioned p. 217 show sudden changes of 15 miles an hour when the average strength of wind was under 30 m.p.h., I think such a change as 28 m.p.h. is quite within the limits of possibility with a wind of 50 or 60 m.p.h.; and it might easily be exceeded by a careless use of the elevator, causing partial stalling of the aeroplane.



If the engine should fail at the same time as the loss of velocity occurs, which is quite conceivable, the resultant dive will, of course, be deeper than if the engine is pulling, and since our object is to ascertain a safe height for flying, *the following calculations are made with the engine stopped.*

It is also assumed that the pilot has full control over the elevator, so that he can regulate the angle of incidence as he pleases, and counteract any effect due to the moment of inertia of the aeroplane about a transverse axis. The area of the elevator is about 25 sq. ft., which, if deflected 20° at a speed of 62 m.p.h., would give a pressure of about 210 lbs. at a distance of 16 ft. from the centre of gravity, or a couple of 3,360 ft.-lbs. Since the moment of inertia of the aeroplane is given as 1,300 ft.^{2} lbs., this would give an angular acceleration of about 2·6. At a speed of 50 ft. per sec., or about 34 m.p.h., it would give about ·8.

The calculations show that generally this is sufficient for the purpose, but at one or two points where there is a sudden change in the angle of incidence this change may require a fraction of a second more time than has been allowed. Also at the beginning of the dive the aeroplane must make a sudden swing downward, for which the elevator would be insufficient if the gust of wind were absolutely instantaneous, as the elevator would take about $\frac{3}{4}$ sec. to give the necessary downward swing. As, however, no gust is absolutely instantaneous, but takes perhaps $\frac{1}{2}$ sec. or more to develop its full force, the elevator has probably sufficient time for the purpose. In no case can this assumption lead to more than a small error.

While sufficient for the above purpose, it is also assumed (which is only approximately true) that the variations of force on the elevator may, in calculating the motion of the centre of gravity of the aeroplane, be neglected in comparison with the pressures on the main planes.

In the first calculation (the results of which are given in Fig. 1), the aeroplane with velocity of 50 ft. per sec. in a horizontal direction starts from o. The pilot puts the elevator hard down, so as to make the aeroplane not only swing downwards in conformity with the natural trend of its course, but to reduce the angle of incidence so as to make the head resistance a minimum, and recover velocity as rapidly as possible. This is attained when the angle of incidence is -1° as measured from the chord. This still leaves a slight lift, as the neutral axis is at an angle of about $-2^\circ 30'$, *i.e.*, the chord must be inclined downwards about $2^\circ 30'$ for the lift to vanish.

The pilot maintains this angle of incidence till the expiration of $2\frac{3}{4}$ secs., when he has approximately attained his normal velocity of 91·6 ft. per sec. He then puts his elevator hard up, so as to increase his angle of incidence to the critical angle of $12\frac{1}{2}$ per cent., which is supposed to be obtained in $\frac{1}{4}$ sec., viz., at 3 secs. (strictly, it would take between $\frac{1}{4}$ and $\frac{1}{2}$ sec.), and he then manipulates the elevator so as to maintain this angle of incidence till the completion of the flattening out, which occurs at 4·4 secs. when his velocity is 95·8, or slightly in excess of the normal 91·6. The total vertical fall has been about 184 ft., and it may be noted that the actual flattening out (from a downward inclination of about 55°), which has been accomplished as rapidly as possible, has taken about 75 ft.