in which the angle of minimum drag falls between them. It is evidently possible therefore to work at a higher maximum speed in circular than in horizontal flight. This is borne out in Fig. 5 by the fact that the system of "constant radii" curves ultimately cuts AD at a series of points, such as D, corresponding to a higher speed than that at B, viz., the

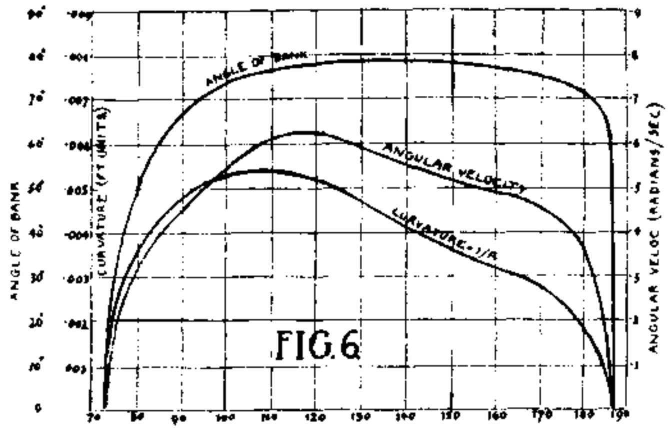

FIG 6

maximum speed of horizontal flight. The difference is, however, comparatively small, in this case not amounting to more than 2 m.p.h.

Fig. 6 gives the maximum curvature of the path possible, the maximum angle of bank and the angular velocity for various speeds.

A rigorous treatment of the problem of circular flight would be extremely complicated owing to the introduction of certain imperfectly known factors dealing with the variation in wind forces along the wings due to the rotation.

Spiral flight.—It has just been demonstrated that circular flight without side-slipping will take place when both the rudder and banking are made use of. If the machine be supposed at the same time to drop or climb with constant velocity, the path traced out will be a helix. It is proposed to determine the relations that exist between the forces operating, and the various quantities that determine the setting of the machine when the latter is travelling with constant speed V along a vertical helix of inclination θ at each point to the horizontal, formed along the surface of a cylinder of radius r. Assume as before that the controls have been fixed in the appropriate positions so that the axis of the machine is along the flight path and neglecting the relatively small cross-wind force on the rudder. Defining the angle of bank by the inclination of the plane of symmetry to the vertical plane through the axis of the machine, and resolving forces along the tangent to the path, along the normal and binormal, Fig. 7, the equations of motion become—

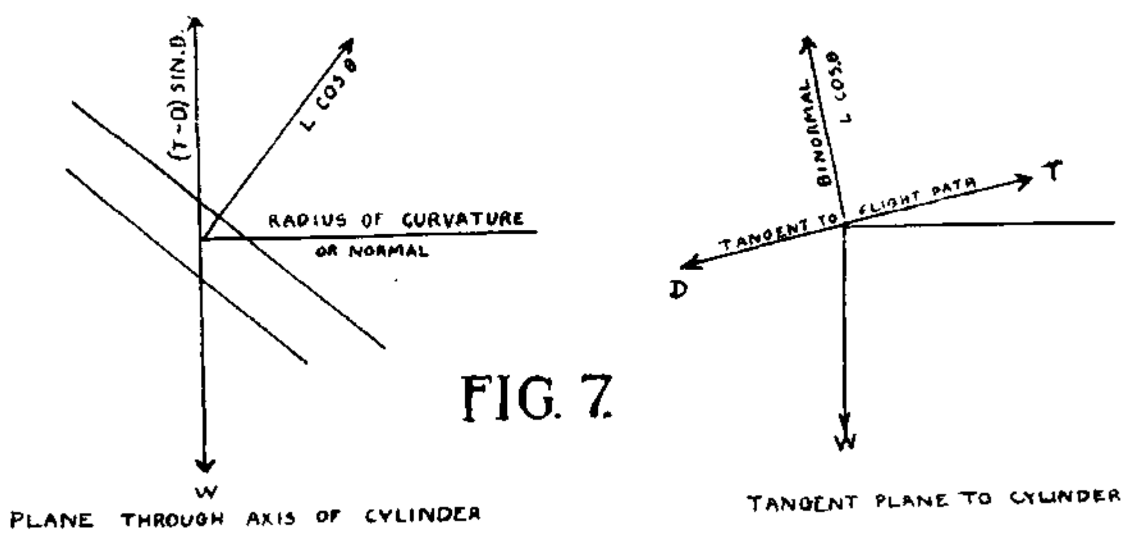

FIG. 7.

$$T - D = W \sin\theta \qquad (11)$$
$$L\cos\phi = W\cos\theta \qquad (12)$$
$$L\sin\phi = W/g . V^2/R \qquad (13)$$

since the normal is along the radius of the cylinder and the radius of curvature of flight path $= R = r/\cos^2\theta$.

It follows that the angle of bank for a given helix defined by R and θ and for a given velocity V is determined from

$$\tan\phi = V^2/gR\cos\theta. \qquad (14)$$

From equation (12) the lift coefficient for this flight becomes

$$L_c = W/\rho AV^2 . \cos\theta/\cos\phi.$$

Writing equation (11) in the form

$$TV = DV + WV\sin\theta \qquad (15)$$

the available horse-power under these conditions may be obtained. The term $WV\sin\theta$ is at once found for various values of V and θ. Following the lines indicated in the case of circular flight, the horse-power necessary to overcome the drag at various velocities in spiral flight can be derived from the horse-power curve for horizontal flight.

Let H_1 = this horse-power during spiral flight and H_2 = the horse-power for horizontal flight at the same speed, then

$$H_1/H_2 = D_1V/D_2V = (D_c)_1/(D_c)_2.$$

Moreover $\quad L\cos\phi = W\cos\theta.$

Hence $\quad W = A\rho(L_c)_1 V^2 \cos\phi/\cos\theta,$

and $\quad W = A\rho(L_c)_2 V^2$

for horizontal flight at the same speed.

Therefore $\quad (L_c)_1/(L_c)_2 = \cos\theta/\cos\phi.$

If V_1 be the horizontal velocity corresponding to the same angle of attack as in the spiral flight, then

$$W = A\rho(L_c)_1 V_1^2,$$

therefore $\quad V^2/V_1^2 = (L_c)_1/(L_c)_2 = \cos\theta/\cos\phi.$

so that $\quad V_1 = V\sqrt{(\cos\phi/\cos\theta)} \qquad (16)$

Now $\quad H_2 = D_2V = A\rho(D_c)_2 V^3.$

Let H'_1 = the horse-power required for horizontal flight at the equivalent velocity V_1, then

$$H'_1 = A\rho(D_c)_1 V_1^3,$$

therefore

$$(D_c)_1/(D_c)_2 = H'_1 V^3/H_2 V_1^3 = H'_1/H_2 . (\cos\theta/\cos\phi)^{3/2}.$$

Hence finally $\quad H_1 = H'_1(\cos\theta/\cos\phi)^{3/2}. \qquad (17)$

Since θ is supposed given and ϕ has been determined in terms of θ, V and R, this equation provides a means of obtaining the horse-power to overcome the drag during spiral flight at velocity V in terms of the corresponding horse-power for horizontal flight at the velocity $V\sqrt{(\cos\phi/\cos\theta)}$.

This will provide a system of curves for all values of R for each value of θ. By the same process of argument developed for circular flight, the various characteristics such as the minimum radii of curvature of flight path, are determined. It is evident that the presence of the term $WV\sin\theta$ in equation (15) corresponds to an extra expenditure of horse-power for climbing beyond that required for circular flight, so that the minimum radii of curvature for spiral climbing will be greater than that for circular flight.

The Latest Gotha

"By chance I was recently led into the great hall at Döberitz, where, now the War is over, giant Gothas lie in repose," writes the *Daily Mail* correspondent in Berlin. "I was allowed to inspect one machine of gigantic proportions. Its span of wing was 160 ft. I cannot give other details, except that it cost £50,000 to build. The machine had never been up, except in trial flights. It was just about to start a new series of raids on Paris when the armistice stopped it."

The Polish Aviation Service

WRITING from Warsaw, and dealing with the lack of equipment in the Polish armies where they are making a stand against the Bolsheviks, Mr. J. M. N. Jefferies, the *Daily Mail* correspondent, states that the Poles have 14 aeroplanes, mostly old training machines, in which machine guns and other military gear have to be haphazardly mounted as best can be done. Efforts are being made to buy some more at Vienna, 10 or so, at whatsoever price.