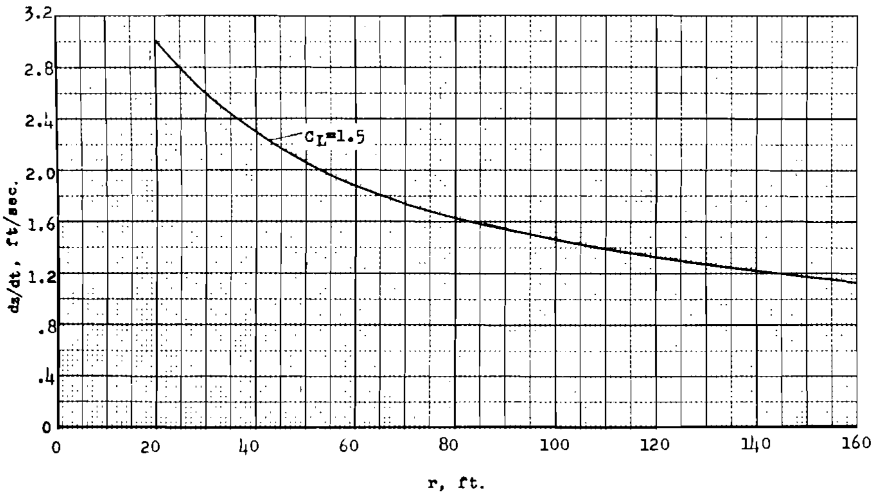

Fig. 5. The relation dz/dt (r) between sinking velocity and radius of turn. Note: $dz/dt = \dot{z}$.

simultaneous values of r and $\dot{z}$ are obtained with α as parameter. Of course, if the drag polar can be expressed analytically in the form $C_D = f(C_L)$, then r and $\dot{z}$ can be related through C_L as parameter directly. Thus we may construct for any sailplane a plot of $\dot{z}$ against r for any values of the pseudo-variables ρ, β, and W/S. Such plots allow us to determine precisely what the aerodynamic sinking velocity will be for a given radius of turn, with of course a specified β. The general nature of this relation is shown in figure 5. This curve was calculated for the specific case where W/S = 1.23 lb./ft^2, $\beta = 30°$, $\sigma = \rho/\rho_0 = 1$, and $C_D = C_{D_i} = C_L^2/7\pi$, $C_{D_0} = 0$. It is the approximate relation for a soaring bird.

The relations of equations (7) and (11) are exact in the sense that no significant assumptions or simplifications have been made in their derivation. The equations are valid, however, only if the wing span b of the plane is small compared to the radius of turn. When this condition is not met, as when a high aspect ratio sailplane executes a tight turn, these relations are no longer exact unless a polar is used which accounts for the variation of velocity across the span. In such tight turns very detrimental and dangerous effects occur so that maximum efficiency in thermal soaring may be impossible with high aspect ratio sailplanes. This subject is discussed in the next section.

MECHANICS OF THERMAL FLIGHT

Let us now consider the actual flight of a sailplane in a thermal shell such as previously described (figures 2, 3). Let us assume that at the altitude of the thermal shell the horizontal wind velocity has a value W′, so that the shell which is rising with velocity V′ is also floating along with the wind with horizontal velocity W′ (figure 6). A sailplane now enters at the top of the shell, say, and feeling the lift begins to circle with a turn radius r. Since near the top of the thermal the velocity of the air relative to the thermal core approaches zero, i.e. $v \rightarrow o$ as the shell stagnation point is approached, the sinking velocity of the plane relative to the air, $\dot{z}$, will be greater than v so that the plane will sink relative to the core. At the same time the plane may be either rising or sinking relative to the earth, depending upon V′, the vertical velocity of the shell as a whole, since the *absolute* velocity of the air at the given radius ($= V' + v$) may be greater or less than $\dot{z}$. As the craft sinks relative to the core it may ultimately reach some plane η in the upper half of the thermal where $\dot{z} = v$, since v increases towards the plane of the core. Here the sailplane will be in stable equilibrium with the shell once it has established a circular

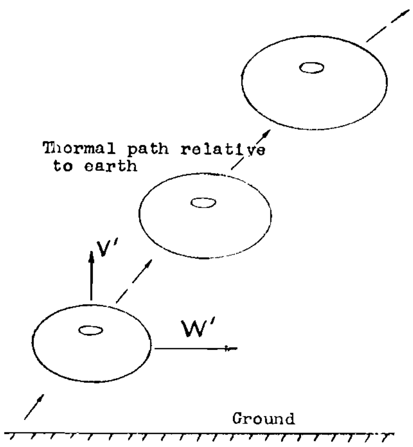

Fig. 6. Path of a thermal shell.

orbit about the vertical axis and will travel along with the shell (see figure 2). The equilibrium is stable in the upper half of the thermal since the value of v increases towards the core plane. If the radius of turn is increased or decreased, the craft will automatically rise or sink to a new equilibrium position (r, η) within the thermal, provided of course that r is not made so large that the craft passes out of the thermal or so small that $\dot{z}$ exceeds the maximum value of v at that radius.

The forces which cause the craft to circle are of purely aerodynamic origin and hence, once equilibrium has been established, the plane will automatically retain its position relative to the thermal axes, making circle after circle without any control regulation by the pilot. The plane will then be carried along with the wind at velocity W′ and will rise relative to the earth with velocity V′. It is important to note that no matter what equilibrium position the craft assumes in the thermal shell, the rate at which it will rise relative to the earth is still V′; it cannot rise at any other speed. Thus, once equilibrium is established, flight is quite automatic and stable.

This idealized picture is of course not fully realized in nature. The air is somewhat turbulent, the thermal is not truly symmetrical, and in general is changing its shape and velocity distribution as it rises. These factors, however, do not affect the ability of a sailplane to use the thermal; they only require some degree of control to be exercised. It is indeed probable that for smaller thermals at the lower altitudes, say under 4,000 feet, the motion will be quite symmetrical and smooth.

If by chance the sailplane had entered the shell at a level below the core plane (η —), it may still be able to attain equilibrium. Provided the entry is made close enough to the core plane that a radius can be found where $\dot{z} = v$, equilibrium will be established and the sailplane will rise with the shell. The equilibrium in the lower half of the thermal is unstable, however, and if the craft is slightly displaced upward it will continue to rise until it reaches a new