Slope Soaring

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THE art of slope soaring has been known to man since Orville Wright made his flight of 9¾ minutes at Kitty Hawk. Since that flight, however, much has been learned about that soaring technique. The acquisition of each morsel of knowledge was marked by new records for motorless flight. Consistent duration flights which indicated man's control over the natural phenomenon connected with slope soaring were initiated by Dr. Wolfgang Klemperer's 33 minute flight from the Wasserkuppe in 1921. How much was actually known about the slope currents is not certain; suffice it to say that the early motorless flyers were able to extract energy from the up-winds on the slopes whether the actual mechanism of this process was known or not.

The reader will note that the writer has been rather discreet in referring to slope soaring as an art. Such it still is. As late as 1936 Professor D. Brunt (1) mentioned the necessity for a scientific study of hill currents. Several years before, Dr. K. O. Lange (2) had made an experimental study of the flight paths of free balloons over slopes. To date, the problem has not been solved with any degree of success. The following analysis is offered not as an ultimate solution to the problem, but rather as a quantitative rule for determining the vertical velocities over any point on a ridge.

The theoretical solution of the two-dimensional flow of a non-viscous incompressible fluid over an extended obstacle such as a ridge is given by Milne-Thomson in his book "Theoretical Hydrodynamics." Since this solution is based on the flow around a linear source in a uniform stream, the results obtained will be exact only for a long extended ridge corresponding to this flow. Furthermore, this solution is based on potential flow and does not, therefore, consider temperature instability in the acceleration of the flow. The application of this theory to soaring will be made without burdening the reader with much of the higher mathematics. We refer to the figure in which h is height of the ridge, V is the horizontal wind velocity, O is the origin of polar coordinates r and θ, and A is the stagnation point at the base of the ridge. The vertical velocity of the air flow over any point on the ridge, is given by

$$v = \frac{Vh}{\pi r.} \sin \theta \qquad \text{(Equation 1)}$$

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The vertical velocity along each of the curves (circles tangent to each other and the horizon at O) is a constant. For practical use the curves have been calculated for a wind velocity of 20 mph and a ridge 800′ high. At a point directly above O the height of the ridge is 400′. The value of "v" is a maximum here and is equal to 19 fps.

It would be interesting to calculate the lift at a point 5 miles to windward of a ridge 500 feet high when the wind velocity is 20 mph (30 fps).

$$v = \frac{30 \times 500}{\pi \times 5 \times 5280} \sin \theta = 0.5 \sin \theta$$

At such a great distance from the ridge the sin θ would be small for the usual flight altitudes. Suppose, for example, the glider were 1 mile high. The sin θ would be approximately 0.2 and the velocity becomes 0.1 fps. This estimate shows that in the example quoted by Jay Buxton (3) in which he cited an instance where lift was felt 5 miles from a ridge, the lift was not due to deflection currents from the ridge but rather to a thermal convection.

The maximum height to which a sailplane can rise over a ridge can also be obtained from the equation of vertical velocity. The maximum altitude for slope soaring is given by the value of "r" at which the lift is exactly equal to the sinking speed of the glider. Looking at the curves in the figure, one sees that the maximum height will be obtained directly over the point "O" which is a distance approximately one-third the height of the ridge from the base "A."

During the meet at Wurtsboro on Dec. 7, 1941, this theory was beautifully confirmed by a flight of Jack Brookhart and a passenger in a Schweizer two-place. In this flight Jack reported that he had to fly at 57 mph at 7250′ in order to stay on the ridge. The horizontal wind speed on the ridge was, therefore, 57 mph or 84 fps. The sinking speed of the Schweizer at this flying speed is given by the manufacturers as 4 fps. (4) The maximum altitude over the *1060* foot ridge (5) is found by solving equation 1 for "r"—

$$r = \frac{84 \times 1060}{4 \times \pi} = 7100'$$

The actual altitude to which Jack Brookhart climbed after one hour and 48 minutes was 7250′. This result indicates that for the case where convection is absent, the