NOTES ON THE DILEMMA OF DEVIATION FROM COURSE LINE

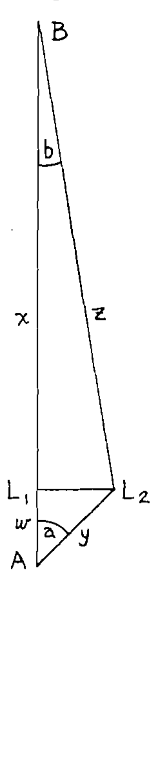
by Rudolph T. Allemann

Suppose that you are flying cross-country in a sailplane. Ahead, on course, you see indications of weak lift, say about 200 ft./min. while off at an angle of 45° from the course there is a cloud which should give 400 ft./min. climb. Would you head for the cloud? What if the cloud were 30° or 50° off course?

The answer to the problem of how far to deviate from the course line depends on many factors such as; strength of lift, location of lift and sink, wind, sailplane, pilot skill, and the situation in general. The following discussion shows the effect of some of the variables and is an attempt to define the problem somewhat mathematically. The results can aid the pilot in making decisions in cross-country flying.

Assume that in Figure 1 a pilot is trying to go from A to B in the shortest possible time. The lift available on course is L_1 and off the course at an angle a from the course line is other lift L_2. Assume that L_2 is greater than L_1 or there would be no reason to deviate from course. (In practice the pilot will have to judge from knowledge and experience what strength of lift is available just as he does when using a MacCready Optimum Airspeed Selector.) The total time it takes to fly the direct distance is $(x+w)/S_1$, where S_1 is the average speed attained along route 1. Similarly, the total time via route 2, utilizing lift L_2 is $(y+z)/S_2$, where S_2 is the average speed attained.

Figure 1.



When the time is the same either way one has

$$(x+w)/S_1 = (y+z)/S_2. \qquad (1)$$

If point A is near the beginning of the course, the deviation distance y, can be appreciable before angle b is very large. If the angle b is small, x is approximately equal to z and equation 1 becomes

$$w/S_1 = y/S_2 \qquad (2)$$

By trigonometry, w = y cos a, so equation 2 becomes

$$(y \cos a)/S_1 = y/S_2, \qquad (3)$$

or

$$S_1/S_2 = \cos a. \qquad (4)$$

The average speeds S_1 and S_2 are dependent on the lift available. Paul B. MacCready, Jr., has pointed out* that for each rate of climb there is an optimum speed to fly for maximum speed. Calculations of the time to climb and time to glide at the optimum speed give values of the best attainable speeds for each lift strength for a given sailplane. Graphs of these attainable average speeds are generally not linear on rectangular coordinate paper. Data for the Ka-6 and the 1-26 have been plotted in Figure 2 on log-log paper. The data in Figure 2 seem to fall on a straight line in the region of most interest. A straight line function on log-log paper is of the form $X = CY^n$, where C is a constant and n is the slope of the straight line. This means that,

$$S \text{ (av. speed)} = C\,L^n \text{ where L is lift strength.} \qquad (5)$$

Combining equation (4) and (5) we have,

$$S_1/S_2 = C(L_1)^n/C(L_2)^n = \cos a = (L_1/L_2)^n \qquad (6)$$

Thus the deviation angle depends on the lift ratio and the sailplane average speed parameter n. The average speed equation for a Ka-6 is determined from Figure 2 to be

$$S = 3.51\,(L)^{0.42} \qquad (7)$$

So for the Ka-6,

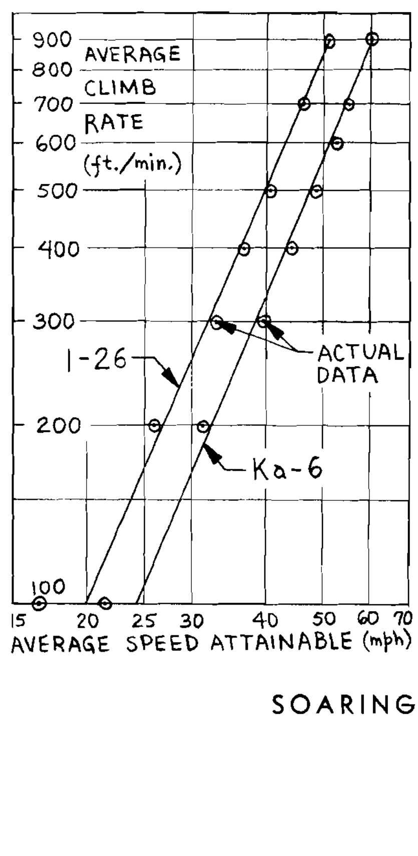
$$\cos a = (L/L_2)^{0.42} \qquad (8)$$

Another look at Figure 2 shows that the slopes for the 1-26 and the Ka-6 are the same. Therefore Equation 8 will apply to the 1-26 as well. Most other sailplanes will also have the same exponent, but some may differ depending on the high speed end of the flight polar.

Equation 8 has been plotted for various values of L_1, L_2 and angle a in Figure 3. (Actually Figure 3 was made by cut and try using the more accurate average speed points in Figure 2, Equation 8 gives almost the same curves but the error on the small lift lines may be up to 5° or 6°, due to the average speed departure from a straight line in Figure 2.)

How does one use Figure 3 then? Example: If the lift is 200 ft./min. on course and 400 ft./min. to the right, in Figure 3 read horizontally along the 400 ft./min line until it intersects the 200 ft./min. on-course-lift line. Then read down to 45°. Hence at angles up to 45° a pilot will increase his speed by deviating to the 400 ft./min. lift. A deviation of more than 45° would be slower than the direct route.

Figure 2. Log-log plot of attainable average speed.



*Soaring, May-June, 1954.