AERODYNAMICS PUZZLER

BY STEVE PLATT

Thermaling

The Glider Aerodynamics Puzzler is intended to stimulate your thinking about soaring and refresh your understanding of glider aerodynamics and soaring optimization. The correct answers with detailed explanations follow the questions. Have fun.

Question 1

On a gorgeous Saturday morning, with an excellent thermal forecast, you are planning on a local recreational glider flight in one of your club's ships. Upon arrival at the airport one of your friends, discussing thermaling techniques, states that she can "outclimb you in any one of the club ships" and challenges you to a thermaling climb contest. She offers you the choice of the two available gliders: a Schweizer 1-26 with a best L/D of 23 and a PW6 with a best L/D of 34. The rules are simple: She will fly whichever ship you do not select. You both will enter the same thermal at the same start altitude at approximately the same time. The thermals are reported to be standard summer thermals (i.e., 4.2 kt air mass lift at the core decreasing parabolically to zero at a radius of 1,000 ft). Which ship do you select? Assuming both pilots fly their ships optimally, and both are centered, who will win and why?

A. The low performance Schweizer 1-26 will outclimb the PW6.

B. The PW6 will outclimb the Schweizer 1-26.

C. Both gliders will perform the same in the same thermal.

D. None of the above.

Explanation

Refer to figure 1. (Reference: May 2017 issue *Soaring* magazine, pg 32, "How to Optimize Thermaling Flight in Gliders"). For all gliders, the optimum bank angle and airspeed to thermal at is dependent upon several factors: the thermal strength at the core, the thermal width (radius) and profile, and the flight polar of the particular glider, especially the level flight minimum sink speed and minimum sink rate … and, of course, how well centered the glider remains. For normal thermals (i.e., strongest at the core decreasing parabolically to the periphery, as shown in figure 1), radius of turn matters. For all gliders the radius of turn is a function of the square of the airspeed and the tangent of the angle of bank as follows: radius = v^2 / (g * Tan(ang)). If a glider flown optimally (i.e., at the minimum sink speed for the chosen angle of bank) flies at too shallow an angle of bank, the radius of turn is large and the glider operates in the weakest part of the thermal close to the periphery or, worse case, circles the thermal. On the other hand, if the glider is flown at too steep an angle of bank, the sink rate increases rapidly with increasing bank angle, more than defeating the benefit of a tight radius of turn. Therefore, for each glider, and for each thermal profile, there is an optimum angle of bank and airspeed (radius) to use to maximize the net climb rate. In the case of Question 1, the Schweizer 1-26 with a level flight minimum sink speed of 38 mph (33 kt) has a significantly shorter radius of turn than the PW6 with its minimum sink speed of 51 kt. Although the level flight min. sink rate for the Schweizer 1-26 (~1.75 kt) is considerable greater than the min. sink rate of the PW6 (~1.5 kt), the tight radius of turn of the slower ship more than offsets the min. sink rate of the higher performance ship. The answer to Question 1 is A. The 1-26 will outclimb the PW6 with both ships centered and flown optimally. As an aside, notice that the peak net climb rate for the 1-26 occurs at only 22 degrees of bank while the peak net climb rate for the PW6 occurs at 34 degrees of bank. The aerodynamics of thermaling is fascinating.

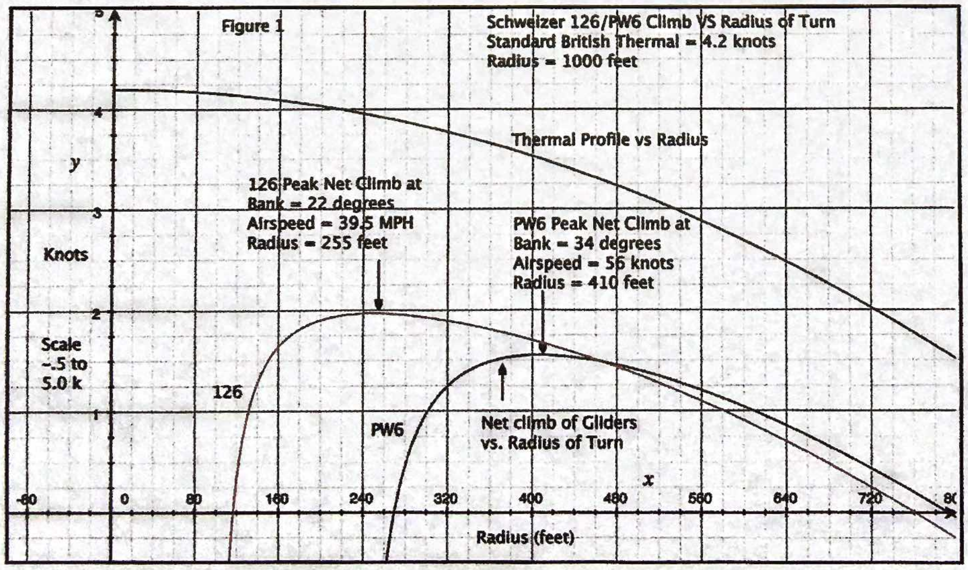

Figure 1: Lesson learned – Radius of turn matters while thermaling. Using the appropriate airspeed and angle of bank while thermaling can enhance net climb performance.

Question 2

You are on the final leg of a cross-country event flying your Super Wingbat 6000 glider. The Super Wingbat's key performance numbers for your operating weight are as follows. (The Super Wingbat's flight polar is shown in figure 2.)

Minimum sink speed = 51 kt.

Best L/D glide ratio = 34.

Best L/D speed = 56 kt.

MacCready 2 speed = 63 kt (no wind).

MacCready 4 speed = 70 kt (no wind).

MacCready 6 speed = 76 kt (no wind).

It has been a glorious day. The thermal lift has been reliable and steady, yielding a net 4 kt, and you have been able to fly with classical MacCready technique all day. As you enter what you expect will be your final thermal prior to your final glide to your home airport, your onboard $9,000 color moving map GPS Navigation computer goes blank. The battery died. You recall before the screen went blank that your final leg is into a 20 kt direct headwind. Your old reliable backup variometer continues to indicate a steady 4 kt climb. Upon reaching the necessary altitude to depart the final thermal, what is the appropriate speed to fly to maximize your average speed (i.e., minimize time) for the final glide into the 20 kt headwind? (Assumption: neutral lift/sink during final glide.)

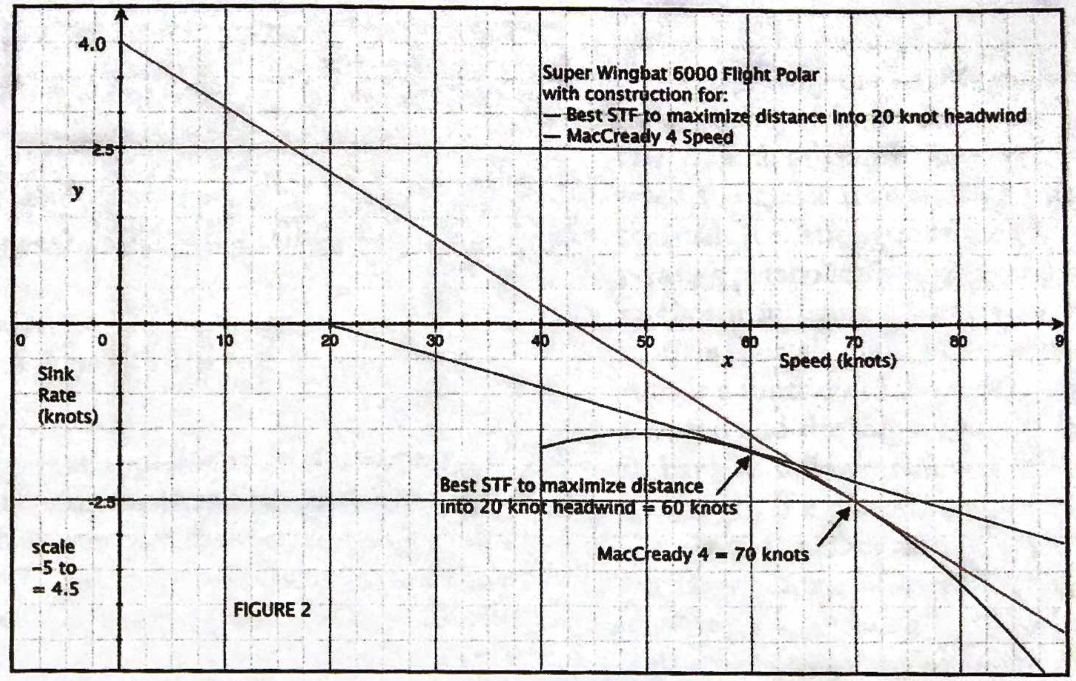

Figure 2: Best speed to fly in 20 kt headwind.

A. Best L/D speed 56 kt.

B. Best STF to maximize distance into 20 kt headwind = 60 kt.

C. Speed to fly = 70 kt.

D. Speed to fly = ~77 kt.

E. Speed to fly = ~82 kt.

Explanation

For the final climb, and the final glide, the headwind (or tailwind) must be taken into consideration for both for the minimum altitude at which the final thermal may be departed, and the optimum speed to fly to maximize average speed (i.e. minimize time). When the expected/actual net thermal climb rate is 4 kt, classical MacCready technique calls a MacCready 4 setting. Likewise, leaving a 4 kt thermal, the final glide into neutral air should be performed at a MacCready 4 setting as well. The optimum speed to fly to maximize average speed for the final climb and glide into a 20 kt headwind, AND the minimum altitude to depart the final thermal, must take the headwind (tailwind) into consideration. Normally, an onboard navigation computer can perform these calculations. However, it is useful to understand what the onboard processor is doing. The optimum speed to fly departing a

4 kt thermal into a 20 kt headwind is determined by the construction to the Super Wingbat flight polar as shown in figure 3. While the normal inter-thermal MacCready 4 speed for this glider is 70 kt (no wind), the optimum speed to fly for the final glide into a 20 kt headwind is ~77.5 kt. The answer to question 2 is D. ~77 kt.

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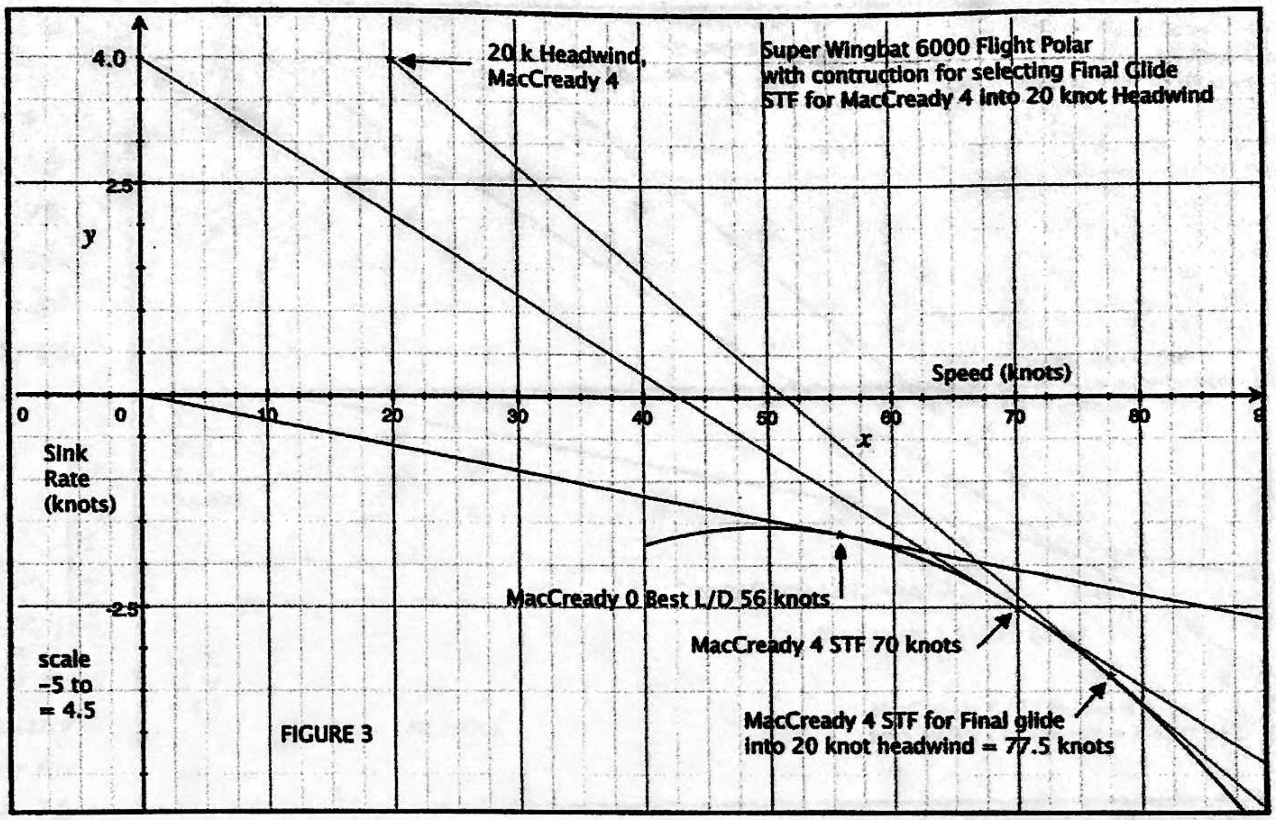

Figure 3: Lesson learned – To optimize average speed for the final climb and final glide, the net average climb rate in the final thermal defines the appropriate MacCready setting. The final glide STF then is adjusted for the headwind (tailwind) which permits the calculation of the minimum altitude to the depart the final thermal. This can all accomplished by an appropriately programmed onboard computer. While it is quite inappropriate to be plotting tangents to flight polars in the cockpit, knowing one's flight polar and a few key parameter scenarios (i.e. key MacCready speeds and adjustments for final glides in 20 kt headwinds) can go a long way toward generating reasonably accurate speeds to fly for various scenarios when all the hardware fails. The alternative, of course, is to purchase and install a second battery!