AERODYNAMICS PUZZLER

BY STEVE PLATT

Weight & Balance Effect on Performance

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.

Questions 1 & 2: Glider pilots understand the effect of weight on glider performance; adding weight (ballast) shifts the flight polar down and to the right. While the best L/D glide ratio remains the same, the best L/D glide ratio speed increases. This, of course, is particularly useful for cross-country flight and competition when lift conditions are strong. Why is the speed benefit a function of the lift conditions? Because climb performance decreases with added weight. The benefit of added glide speed can easily be offset by degraded climb performance. What may come as a surprise to some is the magnitude of the change in key performance parameters with the addition or subtraction of weight (i.e., adding ballast to a single seat ship or flying a dual seat glider solo).

Question 1: For a typical dual seat, medium performance glider [with a best L/D glide ratio of ~34 at ~56 kt at gross weight (e.g., PW-6 or ASK-21)], how much can the best L/D speed decrease at minimum weight, i.e., dual ship flown solo?

A. ~5%
B. ~10%
C. ~15%
D. ~20%
E. ~25%

Question 2: For a typical two-seat, medium performance glider [with a best L/D glide ratio of ~34 at ~56 kt (e.g. PW-6 or ASK-21)], how much can climb performance improve in a typical summer thermal (i.e., Standard British Thermal with 4.2 kt of air mass lift at the core decreasing parabolically to zero at a radius of 1,000 ft) if flown solo at minimum weight versus dual at gross weight? Assume the glider is flown optimally, perfectly centered and flown at the optimum bank angle and airspeed.

A. ~10%
B. ~15%
C. ~20%
D. ~25%
E. ~30%

Explanations

Question 1: First, for ALL gliders with fixed wings (gliders that do not have "re-shapeable" wings, reflex flaps, or flaperons, etc.), the effect of a wing loading (weight) change shifts the flight polar with a simple formula: All polar coordinates shift by a factor equal to the square root of the ratio of the weight change. (References 1 & 2). The coordinates Shift Factor = $(W1/W2)^{0.5}$. This can best be seen by example. Shown in Figure 1 is the flight polar for a PW-6 at gross weight (1,220 lb, dual) and at minimum weight (900 lb, single). The coordinates Shift Factor = $(900/1220)^{0.5}$ = 0.859. Notice that while the gross weight best L/D speed equals 56 kt, at minimum weight (~900 lb) the best L/D speed decreases to 48 kt! A decrease of ~14.2%. The answer to Question 1 is C. What is also very pertinent is that the minimum sink speed decreases from 51 kt at gross weight to 44 kt at minimum weight!

Question 2: As described in the article "How to Optimize Thermaling Flight in Gliders" in the May 2017 issue of *Soaring* magazine, weight matters in optimizing net climb performance in two significant ways. First, as shown in Figure 1, both the minimum sink speed and the minimum sink rate decrease with decreasing weight. While the reduced sink rate helps at lower weights, so does the lower minimum sink speed. Shown in Figure 2, overlaid on the

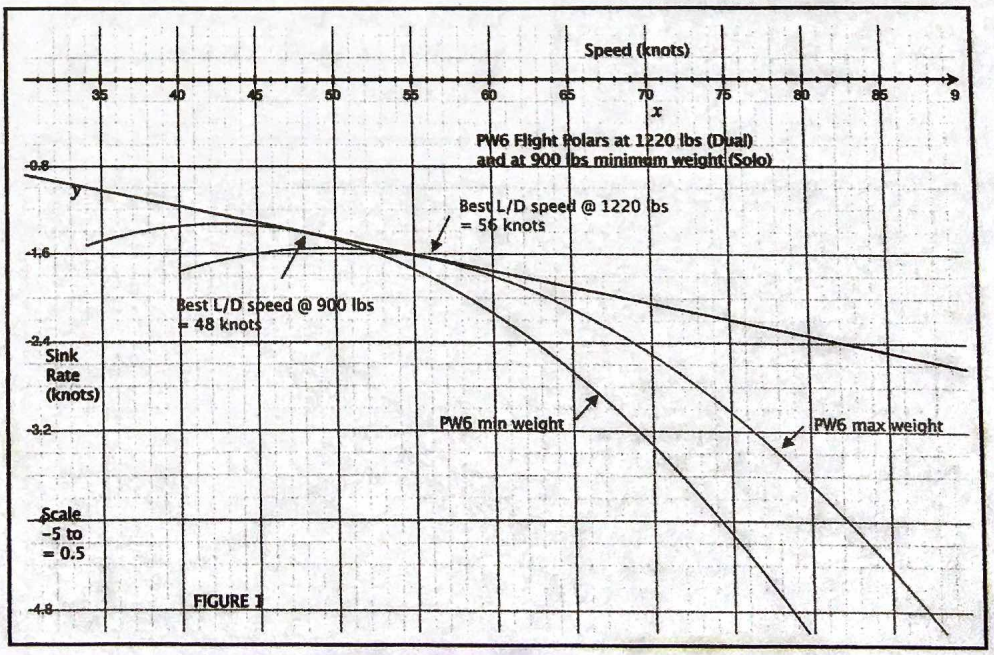

Figure 1 – PW-6 flight polars at 1,220 lb.

profile of a Standard British Thermal, is the sink rate magnitude of a PW-6 at gross weight and minimum weight as a function of the radius of turn (and therefore, as a function of the airspeed and angle of bank) if flown optimally, centered and flown at the minimum sink speed for the angle of bank). Notice that at any radius of turn, the sink rate of the minimum weight configuration is better, and, as a result, the net climb rate (i.e., the thermal profile minus the sink rate of the glider) is considerably better for ALL radii of turns. If flown optimally, the peak net climb rate at gross weight is ~1.6 kt (~160 ft/min) versus a peak net climb rate of ~2.1 kt (~210 ft/min) at minimum weight … or an improvement at the lower weight of greater than 30%! The answer to Question 2 is E. 30%.

Lessons learned

Weight matters in all key glider performance parameters. While glider manufacturers typically publish the flight polar at gross weight and perhaps with ballast if an option, the flight polar at minimum weight (or for a dual ship flown solo) can be significantly different. For ALL gliders at lower weights, the level flight stall speed decreases, the minimum sink speed decreases, and the best L/D speed decreases. And for cross-country flyers, the no wind MacCready speeds decrease as well. For the PW-6 example above, the MacCready 4 speed (no wind) decreases from 70 kt at gross weight to ~62 kt at minimum weight. Not an insignificant difference. For glider pilots with installed navigation computers, it is imperative that the flight polar be entered correctly for the appropriate operating weight, or the software have a setting adjustment for the current operating weight. Otherwise, the speed to fly computations will be, by definition, incorrect.

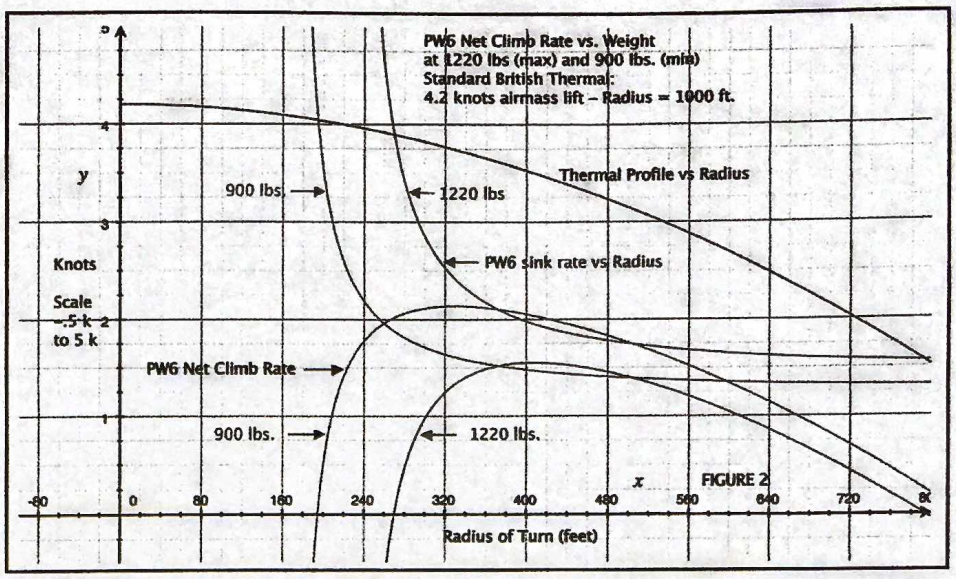

Figure 2 – PW-6 net climb rate vs. weight.

Reference 1: Reichmann, H. (1993). *Cross-Country Soaring* (7th Society of America. (ISBN: 1-883813-01-8).

Reference 2: Welch, A., Welch, L., & Irving, F. G. (1977). *The Complete Soaring Pilot's Handbook*, p 266. NY: D. McKay Co. (ISBN: 0-679-50718-3).

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