Gear and Flaps Down
Part 1

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What happens to the velocity for best glide and the distance you can glide from a given altitude when you put the gear and/or flaps down? To understand these effects we need to look at the power required versus velocity curve in steady level flight, i.e., how does the power required to maintain steady level flight vary with airspeed. This is the hook-shaped curve that you saw back in ground school. The equation for that curve is (I know, math, but it really is the easy and precise way)

$$P_r = \underbrace{\frac{\sigma\rho_{\text{SL}}}{2} f V^3}_{\text{parasite}} + \underbrace{\frac{2}{\sigma\rho_{\text{SL}}}\frac{1}{\pi e}\left(\frac{W}{b}\right)^2 \frac{1}{V}}_{\text{effective induced}}$$

where

b	is the wing span;
e	is the so called Oswald efficiency factor;
f	is the equivalent flat plate area; or the equivalent parasite drag area;
W	is the weight of the aircraft;
V	is the true airspeed (TAS);
ρ_{SL}	(rho sea level) is the density at sea level;
σ	(sigma) is the ratio of the density at altitude to that at sea level ρ/ρ_{SL}.

The power-required curve for a model E33A at sea level, $\sigma = 1$, for a weight, W, of 3300 lbs is shown in Fig. (1).

Recall from your ground school days that the first term on the right hand side of this equation is the parasite power required and the second term is the effective induced power required. The effective induced power required results from the production of lift, i.e., from the lift induced drag. Parasite power required results from all the drag *not* associated with the production of lift, i.e., from all the things sticking out into the airstream.

Also recall from ground school that in steady level flight the thrust required from the propeller-engine combination is exactly equal to the total drag of the airplane. Furthermore, power is equal to the product of thrust and velocity (TAS), i.e.,

$$P_r = TV$$

where T is the thrust achieved by the propeller-engine combination.

Of the terms in the power required versus velocity equation, three are probably unfamiliar and require some additional explanation, σ, e and f. σ (sigma), as mentioned, is the ratio of the density at altitude to that at sea level on a standard day. $\sigma = 1$ at sea level and decreases as the altitude increases. Using σ allows us to investigate the effects of altitude quite easily, but more about that in another article.

The Oswald efficiency factor, e, accounts for the fact that, because aircraft design is a compromise, no wing or airplane is as efficient as is theoretically possible. The theoretical maximum value

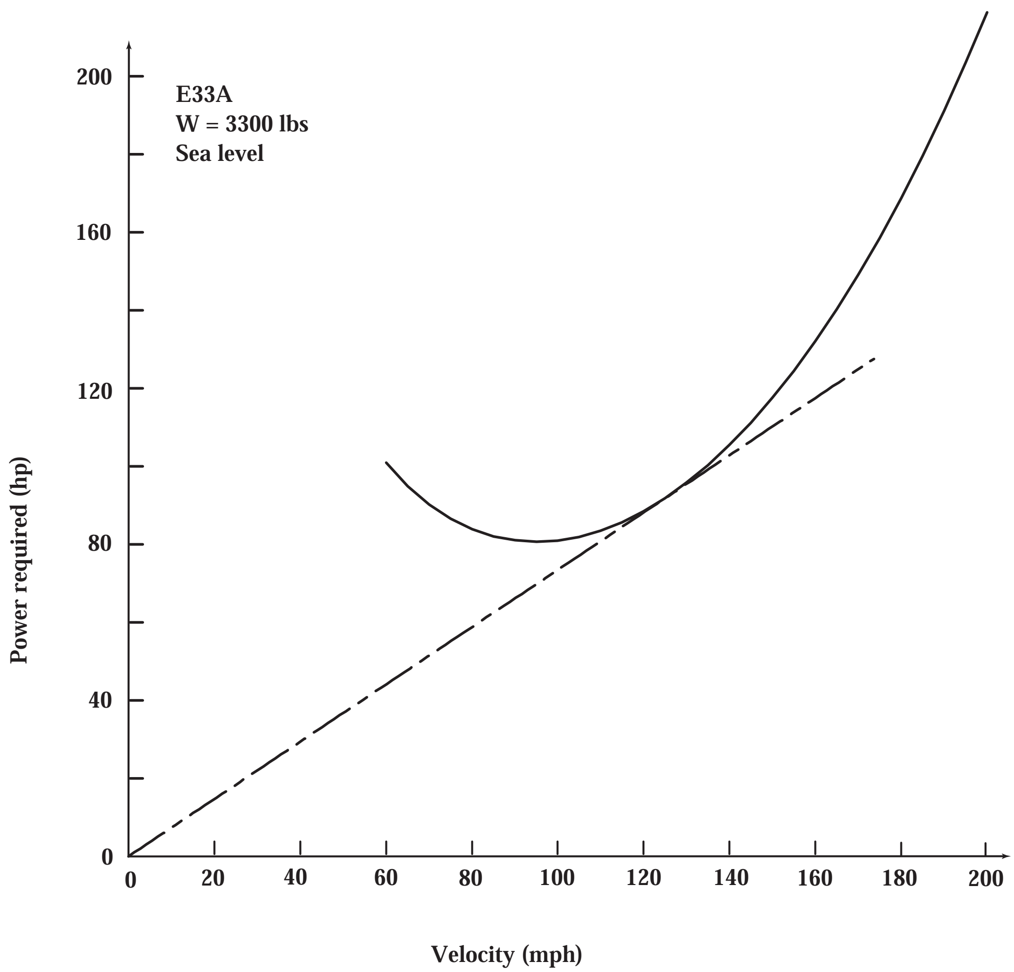

Figure 1. Power required.

for the Oswald efficiency factor is one. The smaller the value of e the less efficient the aircraft. The Oswald efficiency factor affects the effective induced power required, i.e., the power required associated with the production of lift. Typical values for light aircraft are from 0.5 to 0.8. Based on flight test results, the Bonanza, with gear and flaps up, i.e., clean, has an Oswald efficiency factor of approximately 0.56 to 0.65. Extending the gear and/or flaps has some effect, but not a very large one, on the value of e.

The equivalent flat plate area, f, is the size of a flat plate held normal or perpendicular to the air stream which has the same parasite drag as the airplane. The Bonanza has an equivalent flat plate area of approximately 3.5 square feet. To put this number in perspective, this is less than the area of four 12 inch square floor tiles, or a bit more than that of six 9 inch square tiles. As we all know, the Bonanza is a slippery aircraft, and the small value of f is indicative of that fact.

In looking at the power required versus velocity curve in Fig. (1), we see that the curve has a minimum or smallest value at some velocity. This minimum value is given by the equation†

$$P_{r_{\min}} = 2.48\,\frac{f^{1/4}}{\sqrt{\sigma\rho_{\mathrm{SL}}}}\Big(\frac{1}{\pi e}\Big)^{3/4}\Big(\frac{W}{b}\Big)^{3/2}$$

and the velocity (TAS) at which it occurs is given by the equation

$$V_{P_{r_{\min}}} = \Big(\frac{4}{3\pi f e}\Big)^{1/4}\sqrt{\frac{1}{\sigma\rho_{\mathrm{SL}}}}\sqrt{\frac{W}{b}}$$

The $P_{r_{\min}}$ and $V_{P_{r_{\min}}}$ are marked in Fig. (1) with a horizontal line and a vertical line, respectively.

We need one additional concept before discussing the effect of gear and flap extension on the best glide velocity. Notice the alternating short and long dashed line through the origin $(0,0)$ just tangent to (just touching) the power required curve in Fig. (1). The point at which this line just touches the power required curve gives the velocity (TAS) for maximum glide distance. Technically this velocity is known as the velocity for maximum lift to drag ratio, $V_{\mathrm{L/D_{max}}}$ and is given by the equation

$$V_{\mathrm{L/D_{max}}} = \Big(\frac{2}{\sigma\rho_{\mathrm{SL}}}\,\frac{W}{b}\,\frac{1}{\sqrt{\pi f e}}\Big)^{1/2}$$

Now, what happens when we extend the gear (or flaps)? The equivalent flat plate area, f, increases. Look at the equation for $P_{r_{\min}}$. If f increases then the $P_{r_{\min}}$ increases and the curve moves up, as shown by the curve drawn with long dashes in Fig. (2). The drag increases, and consequently the power required to maintain level flight at the same velocity also increases. We know this from experience, but the equation shows why this happens.

Looking at the equation for $V_{P_{r_{\min}}}$, we see that f is in the denominator (on the bottom). If f increases, then $V_{P_{r_{\min}}}$ decreases. Consequently, the curve moves to the left toward a lower velocity (TAS), as shown by the curve drawn with short dashes in Fig. (2). The combined effect is to move the curve up and to the left. This curve is drawn with a solid line.

Now let us look at what happens to the velocity for best glide, $V_{\mathrm{L/D_{max}}}$. The tangent through the origin to this new curve with increased equivalent flat plate area, drawn with alternating short and long dashes, shows that the velocity for best glide significantly decreases compared to the original curve. In addition, notice that f occurs in the denominator of the equation for $V_{\mathrm{L/D_{max}}}$, which also shows that the best glide velocity decreases when f increases. Thus, if you have to glide with the gear and/or the flaps down you need to slow down to optimize the glide distance.

To see what happens to the glide distance when the gear and/or the flaps are extended, look at the angle, γ, between the line through the origin tangent to the power required curve and the horizontal axis. In Fig. (2) this line is shown with short and long dashes for both the original power required curve and for the gear and flaps extended power-required curve. The *smaller* the angle the *farther* you can glide. In fact, this angle represents the ratio of drag to lift,‡ D/L, which is the reciprocal of the lift to drag ratio, L/D. The L/D ratio represents the number of feet you can glide forward

† Do not be concerned about the exponents. You can do these with a simple \$10 calculator which has a square root function $\sqrt{\ }$. The $()^{1/4}$ means take the $\sqrt{\ }$ twice and the $()^{3/4}$ means multiply the quantity by itself twice, and take the $\sqrt{\ }$ twice e.g., $\sqrt{\sqrt{\frac{1}{\pi e}\times\frac{1}{\pi e}\times\frac{1}{\pi e}}}$ and $()^{3/2}$ means multiply the quantity by itself twice and take the $\sqrt{\ }$ once.

‡ Actually. $D/L = \tan^{-1}\gamma$.

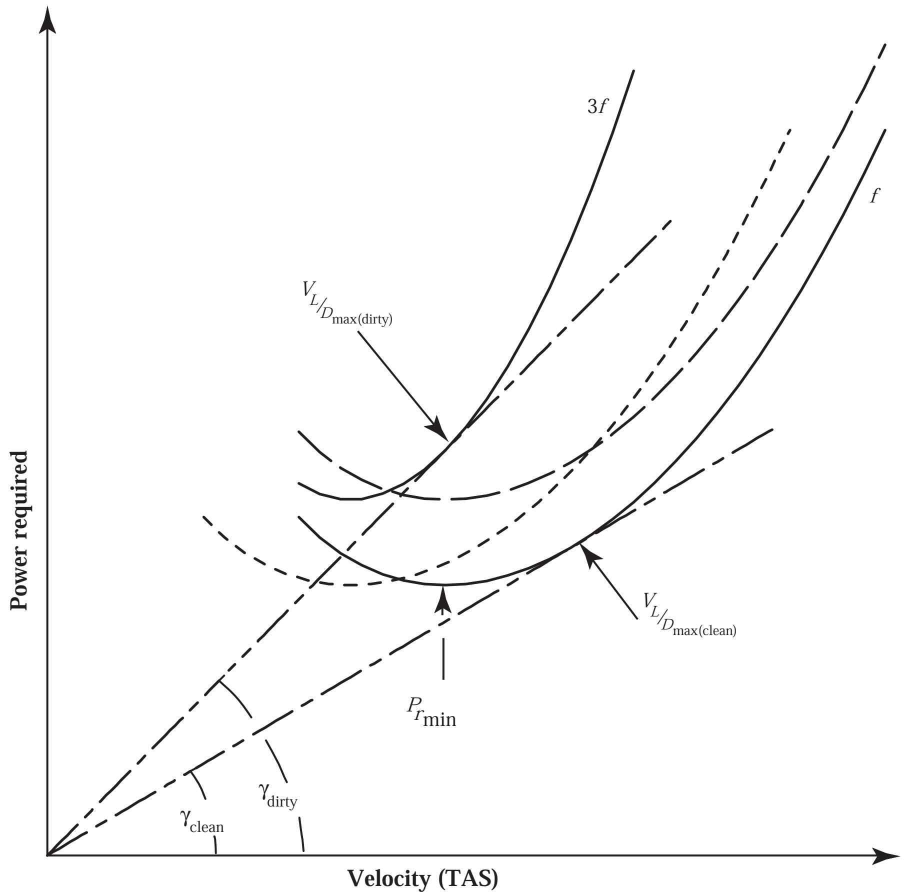

Figure 2. Effect of parasite drag on power required.

for every foot of altitude, i.e.,

$$\text{Glide distance} \quad d = \frac{L}{D}h \quad \text{height above ground}$$

Lowering the gear can more than *double* the equivalent flat plate area. Extending 30° of flaps has a similar effect. Thus, lowering the gear and extending 30° of flaps can more than *triple* the value of f. These are the effects shown in Fig. (2). The values are representative of the Bonanza. Looking at Fig. (2) shows that there is a large decrease in both the velocity (TAS) for maximum glide distance and the actual distance you can glide from a given altitude when you lower the gear and/or the flaps. The decrease in velocity for maximum glide distance with an increase in equivalent flat plate area can be determined from the equation for $V_{\mathrm{L/D_{max}}}$. The ratio of $V_{\mathrm{L/D_{max}}}$ dirty, i.e., with gear and/or flaps down, to that in the clean configuration is

$$\frac{V_{\mathrm{L/D_{max\ (dirty)}}}}{V_{\mathrm{L/D_{max\ (clean)}}}} = \left(\frac{f_{\mathrm{clean}}}{f_{\mathrm{dirty}}}\right)^{1/4}$$

As mentioned, for a Bonanza lowering the gear approximately doubles the equivalent flat plate area, f. Thus, with the gear down

$$\frac{V_{\mathrm{L/D}_{\mathrm{max\ (dirty)}}}}{V_{\mathrm{L/D}_{\mathrm{max\ (clean)}}}} = \left(\frac{1}{2}\right)^{1/4} = 0.84$$

which shows that $V_{\mathrm{L/D}_{\mathrm{max\ (dirty)}}}$ decreases by approximately 16% from the clean best glide speed. For a model E33A at a weight of 3300 lbs, the best glide speed decreases to 103 mph from the clean best glide speed of 122 mph.

For a Bonanza, lowering the gear and extending the flaps to 30° approximately triples the equivalent flat plate area, f. For this configuration

$$\frac{V_{\mathrm{L/D}_{\mathrm{max\ (dirty)}}}}{V_{\mathrm{L/D}_{\mathrm{max\ (clean)}}}} = \left(\frac{1}{3}\right)^{1/4} = 0.76$$

which shows that $V_{\mathrm{L/D}_{\mathrm{max\ (dirty)}}}$ decreases by approximately 24% from the clean best glide speed. For a model E33A at a weight of 3300 lbs, the best glide speed with gear and flaps down decreases to 93 mph from the clean best glide speed of 122 mph. These are significant effects.

One additional very important comment is in order. These results are *only approximate*, because the actual increases in the equivalent flat plate area are not currently known. Some preliminary flight tests indicate that they are about right. More extensive flight tests are in progress. If successful, the results will be reported in future articles. However, even in that case, the results will *only* apply to a specific aircraft.

In Gear & Flaps Part 2, we talk about what happens to the velocity for maximum rate of climb and the actual rate of climb when you have the gear and/or flaps extended. If you look at the power required curve and think about it for a bit, you can anticipate the discussion.