Altitude Effects

Part 2

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In our previous discussion of the effects of extending the gear and flaps we found that the rate-of-climb and velocity for maximum rate-of-climb were both significantly reduced. Further we found that the range of velocities that gave positive rates-of-climb was also reduced. We also took a look at the effects of altitude on both the power required to maintain level flight and on the thrust power available. We found that the power required to maintain steady level flight *increased* with both altitude and when we extended the gear and/or flaps. We also found that the thrust power available *decreased* with increasing altitude. We now have enough information to look at the effects of altitude on the rate-of-climb with gear and/or flaps extended. Knowing the rate-of-climb and the velocity for maximum rate-of-climb is particularly important for those hot high altitude take-offs and go arounds. Again we use a Model 33A at full gross weight as an example.

Since we are concerned only with altitude (density) and parasite drag effects (extending the gear and/or flaps) our power required equation simplifies to

$$P_r = \underbrace{\text{Constant}\,\sigma f}_{\text{parasite}} + \underbrace{\frac{\text{Konstant}}{\sigma}}_{\text{effective induced}}$$

where σ represents the ratio of density at any altitude to the density at sea level, f is a measure of the parasite drag and Constant and Konstant are constants.

Recalling that the rate-of-climb is determined by the excess thrust power available over that required to maintain level flight we see by looking at Figure 1 that at 10,500 feet with gear and flaps extended the aircraft cannot climb. In fact, steady level flight is only possible at the velocity where the thrust power available and power required curves touch, i.e., at a velocity (TAS) of about 82 mph. Since, with the gear and flaps extended the rate-of-climb is zero at an altitude of 10,500 feet this is the absolute ceiling of the aircraft with gear and flaps extended. If you attempt a go around with gear and flaps extended at an airport with a density altitude of more than approximately 10,500 feet the aircraft *can not climb*.

Notice that Figure 1 has a second horizontal axis labelled 'Velocity (EAS) mph'. Up until the present discussion we have consistently used true airspeed (TAS). We all know from ground school that the airspeed indicator does not show true airspeed but rather indicated airspeed (IAS). Also recall from ground school that indicated airspeed (IAS) corrected for installation/instrument errors gives calibrated airspeed (CAS) and calibrated airspeed (CAS) corrected for compressibility effects (which are essentially negligible for our airspeeds) gives equivalent airspeed. Equivalent airspeed corrected for temperature and altitude effects yields true airspeed (TAS). In particular,

$$\text{TAS} = \frac{\text{EAS}}{\sqrt{\sigma}}$$

or

$$\text{EAS} = \sqrt{\sigma}\,\text{TAS}$$

The POH shows that the corrections from IAS to EAS are very small except at very low velocities. Thus, we can consider EAS to be essentially the same as IAS, i.e., the speed shown on the airspeed indicator. From Figure 1 and the equation for the equivalent airspeed the only possible steady level

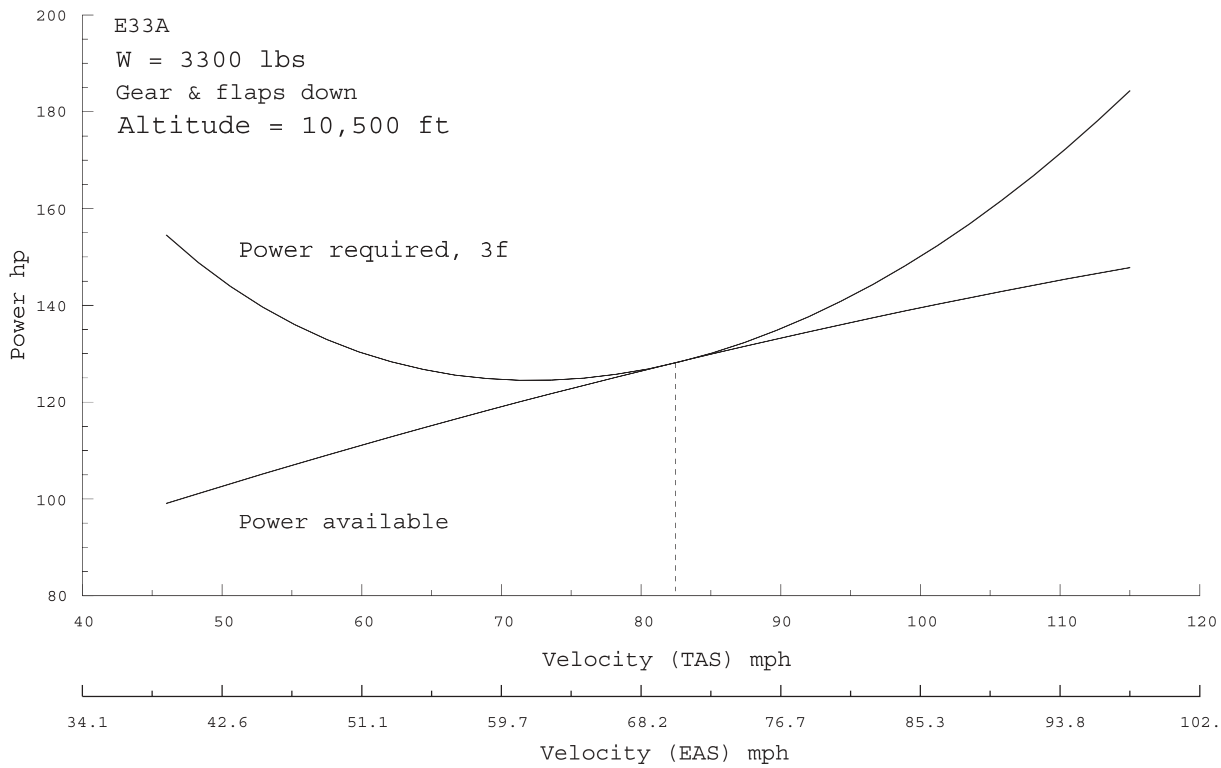

Figure 1. Power available and power required at 10,500 ft. gear and flaps extended.

flight velocity at 10,500 feet with the gear and flaps extended is approximately 70 mph. At any other EAS the aircraft can not climb and in fact, since at any other airspeed the power required exceeds the thrust power available, the aircraft will descend.

Figure 2 shows the rate-of-climb with gear *and* flaps extended (labelled 3f), with gear *or* flaps extended (labelled 2f) and clean, i.e., with gear and flaps retracted (labelled f). Figure 2 confirms our previous observation from Figure 1 that the rate-of-climb at 10,500 feet gear and flaps extended is zero. However, note that retracting either the gear or flaps (see the curve labelled 2f) yields a small positive rate-of-climb of about 190 feet per minute (fpm). Notice also that, as expected, the velocity (TAS) for maximum rate-of-climb increases to approximately 94 mph which corresponds to an EAS of approximately 80 mph.

Operationally this suggests that if you are approaching an airport with a high density altitude and you have enough runway available and you think you might have to go around you should consider using no flaps or less than full flaps during the approach. You might even want to go elsewhere.

If you decide to conduct the approach, you must be aware that using no or less than full flaps, especially at high density altitudes, significantly increases your ground speed. Near the ground this increased ground speed can give you the impression that you are too fast and can cause you to pull-up and stall the aircraft. Don't do that, fly the airspeed indicator and nail the airspeed.

A further consideration is that the POH gives landing distances assuming that full flaps are used. Because of the high approach velocity, landing distances are significantly *increased* when no or less than full flaps are used. So, make sure you have enough runway available. As a first approximation use at least double the required runway length shown in the POH.

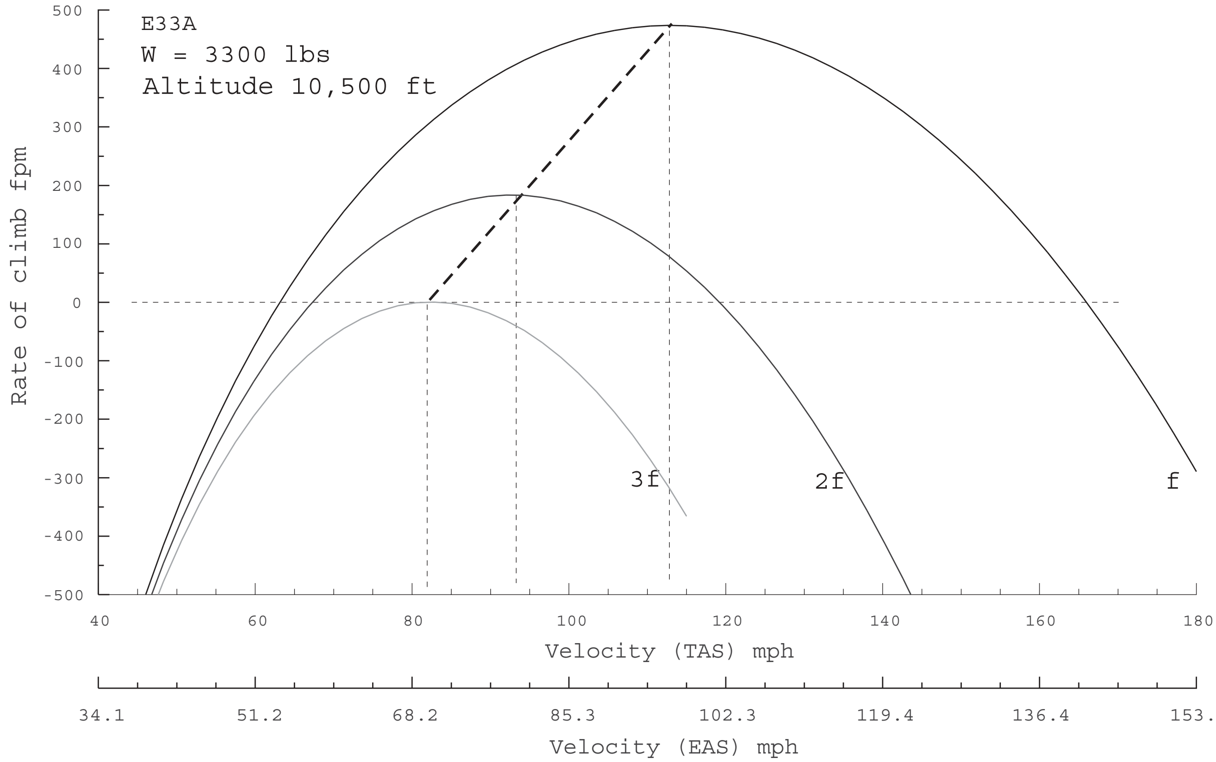

Figure 2. Rate of climb at 10,500 ft with full power.

Figure 2 shows that the EAS for maximum rate-of-climb with gear and flaps extended is close to the clean EAS at which the aircraft stalls. If you use full flaps during the approach at a high density altitude airport and have to go around, Figure 2 suggests a procedure for cleaning up the aircraft. When flaps are extended the largest change in the lift occurs during the *first* few degrees of extension while the largest change in drag occurs during the *last* few degrees of extension. Therefore, if we first retract the flaps to about 10 degrees, we retain most of the increased lift (and reduce stalling velocity) but get rid of most of the parasite drag. This improves the rate-of-climb, because the parasite drag is decreased, and allows the aircraft to accelerate to the higher velocity for best rate-of-climb for the reduced parasite drag. We now have a higher margin over stall velocity or to use to maneuver. If we now leave the flaps extended and retract the gear, again the parasite drag is decreased, our rate-of-climb increases and the aircraft again accelerates to the higher velocity for best rate-of-climb for this new reduced parasite drag. We can now retract the remainder of the flaps and allow the aircraft to accelerate to the velocity for best rate-of-climb in the clean configuration as shown by the curve labelled f in Figure 1, i.e., a true airspeed (TAS) of approximately 112.5 mph which is an equivalent airspeed (EAS) of approximately 96 mph at 10,500 feet. In effect, we are flying the aircraft along the heavy dashed line shown in the Figure 1.

Another question of interest is what is the absolute ceiling with just the gear (or flaps) extended? Figure 3 which shows the rate-of-climb for 13,000 feet gives the answer. Recall that when the gear (or flaps) are extended the parasite drag represented by f doubles. The curve labelled 2f shows that the rate-of-climb with the gear (or flaps) extended is nearly zero at 13,000 feet. Thus, the absolute altitude of the aircraft with the gear (or flaps) extended is 13,000 feet. Figure 3 also shows that the only velocity (TAS) at which the aircraft can is approximately 91 mph or 74 mph

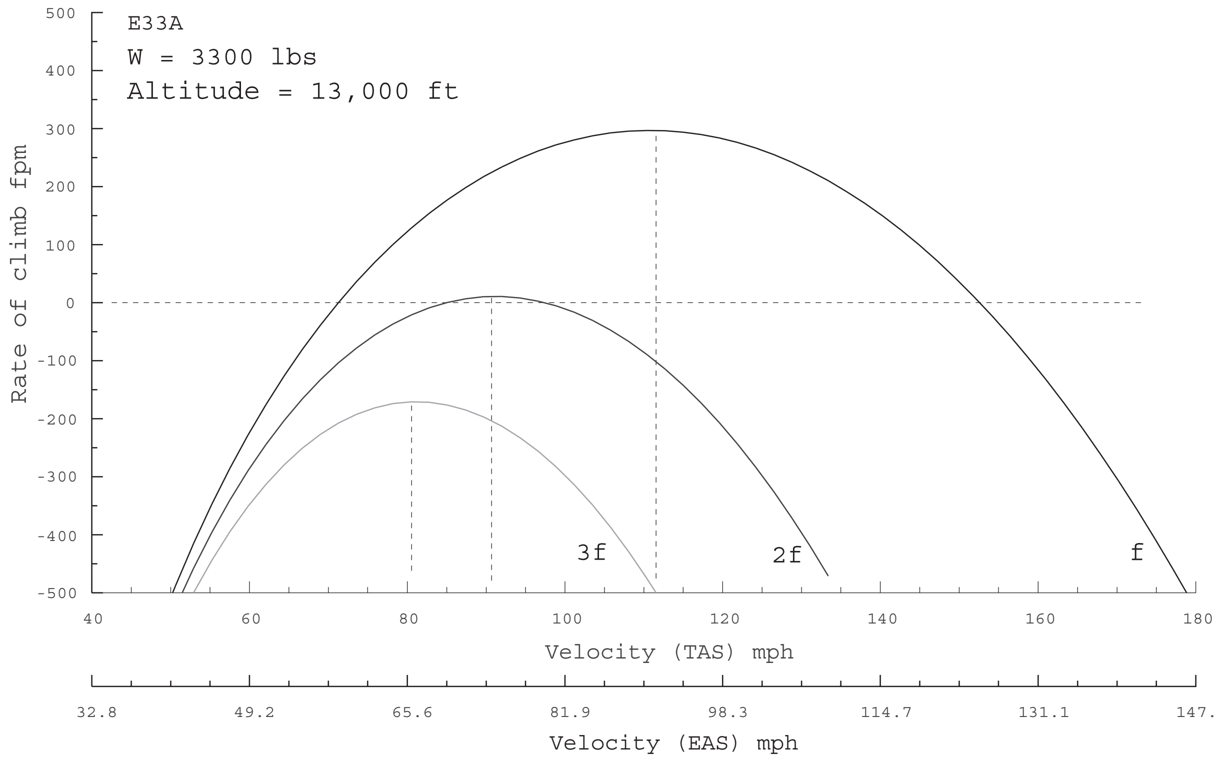

Figure 3. Rate of climb at 13,000 ft with full power.

equivalent airspeed (EAS). Figure 3 also shows that the aircraft will climb in the clean configuration at about 300 fpm at an altitude of 13,000 feet at a velocity (TAS) of approximately 112.5 mph which is an equivalent airspeed of approximately 91 mph.

Looking at the power required and thrust power available curves and the resulting rate-of-climb curves tells us a great deal about *how* the airplane flies and how *to* fly the airplane.

