Turbo-normalization

David F. Rogers

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Have you ever wondered how turbo-normalization would improve your airplane's performance? I have. Let's take a look at it.

First, what is turbo-normalization? Simply put, turbo-normalization uses an exhaust gas turbine to drive a compressor which increases the engine intake manifold pressure. A turbo-normalization system automatically limits manifold pressure to that at sea level at all altitudes up to the system critical altitude. The critical altitude is that altitude above which the system cannot maintain sea level manifold pressure. Thus, maximum sea level engine power is available up to the critical altitude. Above the critical altitude the manifold pressure and consequently the power decrease. The critical altitude for most current turbo-normalization systems is approximately 20,000 feet. Above that altitude the manifold pressure decreases approximately one inch for each thousand feet of altitude.

In contrast to turbo-normalization, turbo-charging increases intake manifold pressure above that at sea level. This is an important distinction. Simplistically, because the air–fuel ratio must be maintained within relatively narrow limits in order to maintain combustion, you can consider an internal combustion engine as an 'air burner'. If you increase the amount of air in the cylinders, then an increased amount of fuel can be burned. Because fuel burned is power available, the horsepower is increased. The price you pay is increased engine wear because of the higher operating pressures and increased heat output.

Although with turbo-normalization the engine brake horsepower available is approximately constant, up to the critical altitude, remember thrust horsepower available also incorporates propeller efficiency, i.e.

$$\mathrm{ThP}_a = \eta \mathrm{BhP}_a$$

where η (eta) is the propeller efficiency.

Although with turbo-normalization the thrust power available remains approximately constant the power required to maintain level flight increases with increasing altitude. Recall from our previous discussions (see Altitude Effects, Parts 1 & 2) that when you consider only altitude effects the power required curve simplifies to

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

where Constant and Konstant are constants.

Figure 1 shows the power required curves for sea level, 5, 10, 15, 20 and 25,000 feet along with the 75% sea level thrust power available curve for an E33A at a weight of 3300 lbs equipped with a three-bladed propeller. With a full power typical critical altitude of 20,000 feet, a turbo-normalization system can maintain 75% sea level power at 25,000 feet. Figure 1 indicates that at sea level the 75% power cruise velocity (TAS) is approximately 189 mph (164 kts) which is close to the value of 187 mph (163 kts) for the normally aspirated engine at 3100 lbs given in the POH. With turbo-normalization, the 75% power cruise velocity (TAS)

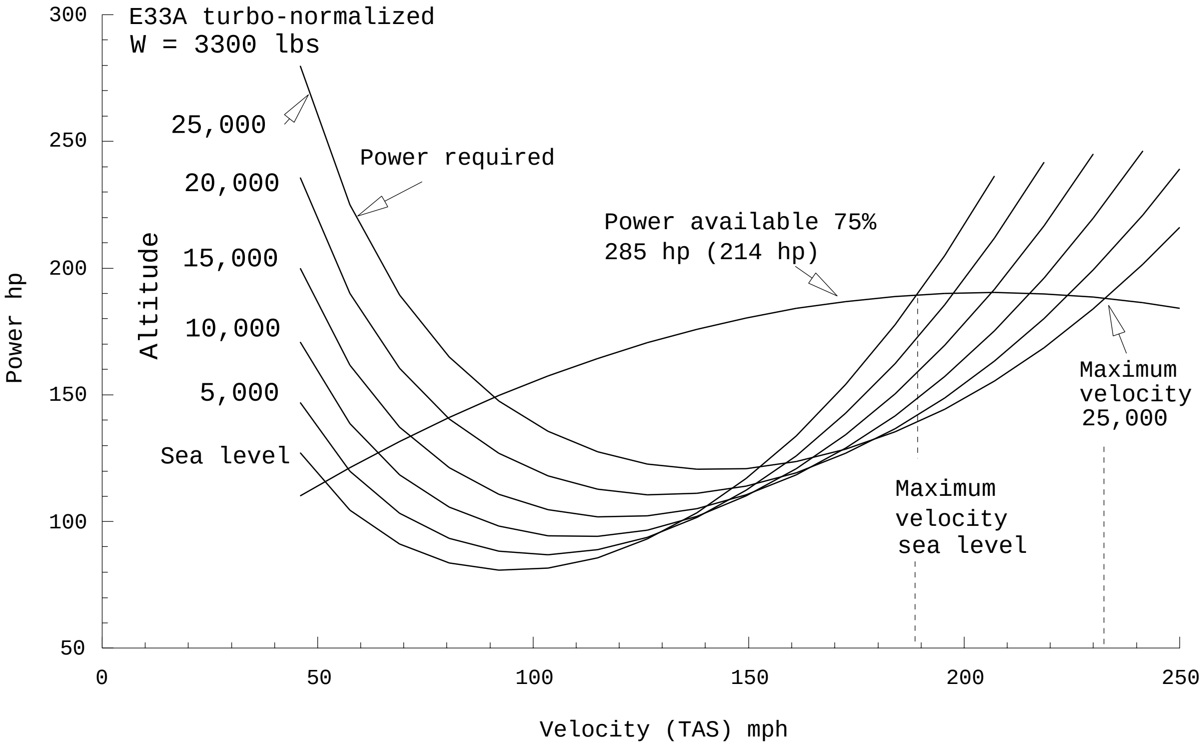

Figure 1. Power power required vs velocity.

at 25,000 feet is approximately 232 mph (202 kts). Figure 2 compares the 75% power cruise velocity for the turbo-normalized engine with that for the normally aspirated engine at full throttle and 2500 rpm. Above 6500 feet the difference is striking. With turbo-normalization the velocity continues to increase with altitude, while for the normally aspirated engine the velocity decreases because the engine can no longer maintain 75% of sea level power available.

Figure 3 compares the full power maximum rate-of-climb for a turbo-normalized engine with that for a normally aspirated engine. Figure 4 compares the full power velocity for maximum rate-of-climb for a turbo-normalized engine with that for a normally aspirated engine. Again, the differences are striking.

These differences considerably reduce the time required to climb to a given altitude. Assuming a full power climb at the maximum rate-of-climb, the time to climb to 10,000 feet is 11.62 minutes for an aircraft with a normally aspirated engine and 7.87 minutes for the turbo-normalized engine, i.e., about two-thirds the time for the normally aspirated engine. The difference in time-to-climb to 15,000 feet is even more striking; 26.88 minutes for the normally aspirated engine, and 12.25 minutes for the turbo-normalized engine, i.e., less than half the time (46%) for the normally aspirated engine.

Recalling our previous discussion of the effects of extending gear and flaps turbo-normalization also has significant positive effects for that hot high altitude take-off or go

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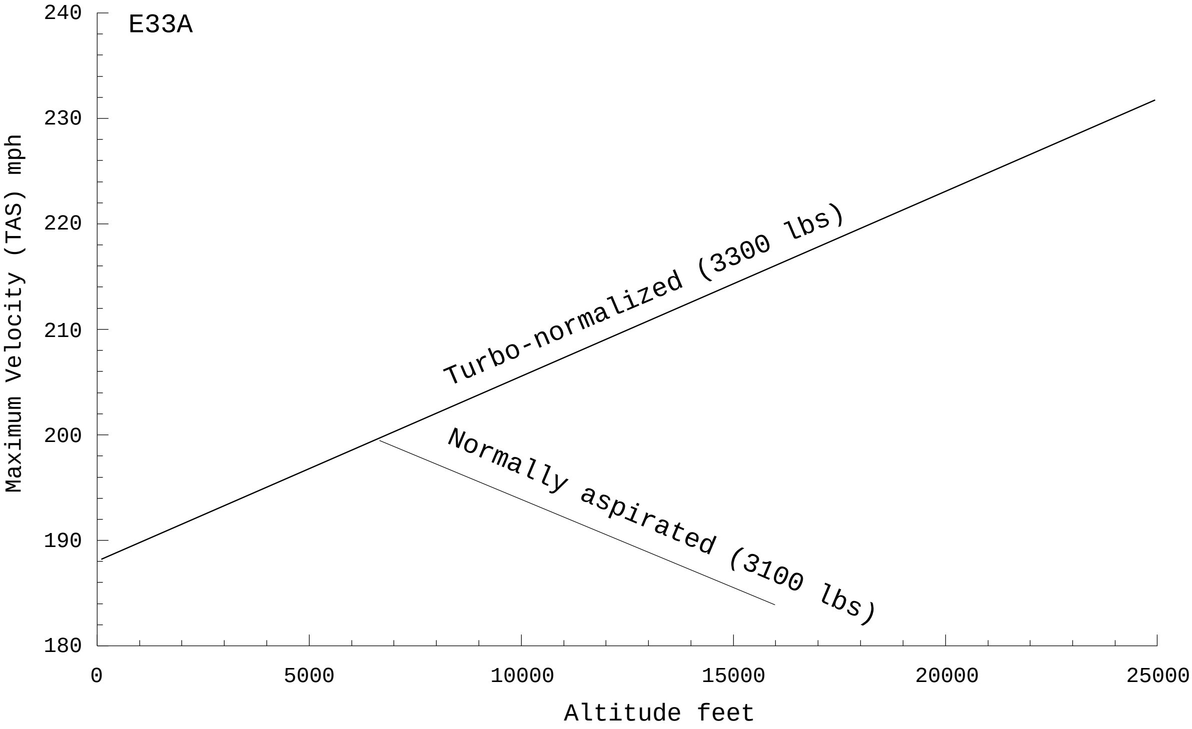

Figure 2. Maximum velocity vs altitude.

around. However, turbo-normalization is not without its price. Because of increased fuel consumption at the higher operating powers, range is decreased. The decreased density of the air at the higher altitudes may result in marginal cooling. Further, at the altitudes where turbo-normalization is most advantageous supplimental oxygen is required. Finally, if you consistently operate at higher power increased engine wear results. As with anything in aviation, turbo-normalization is a compromise.

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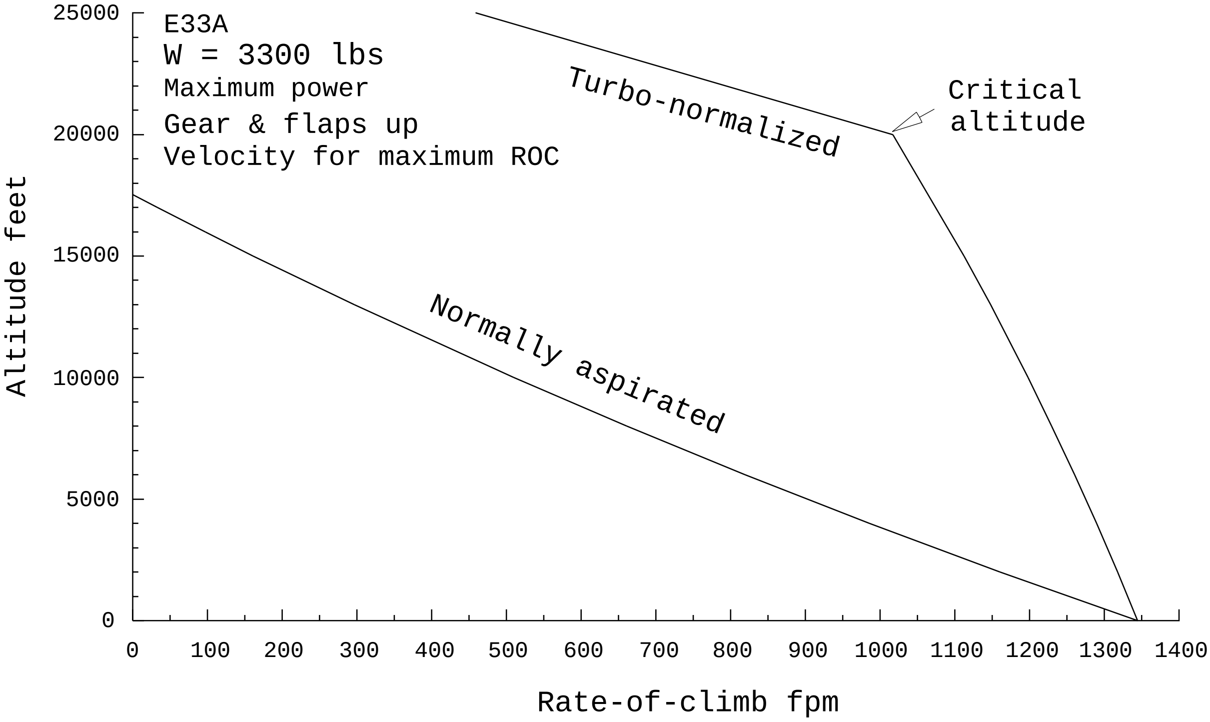

Figure 3. Power power required vs velocity.

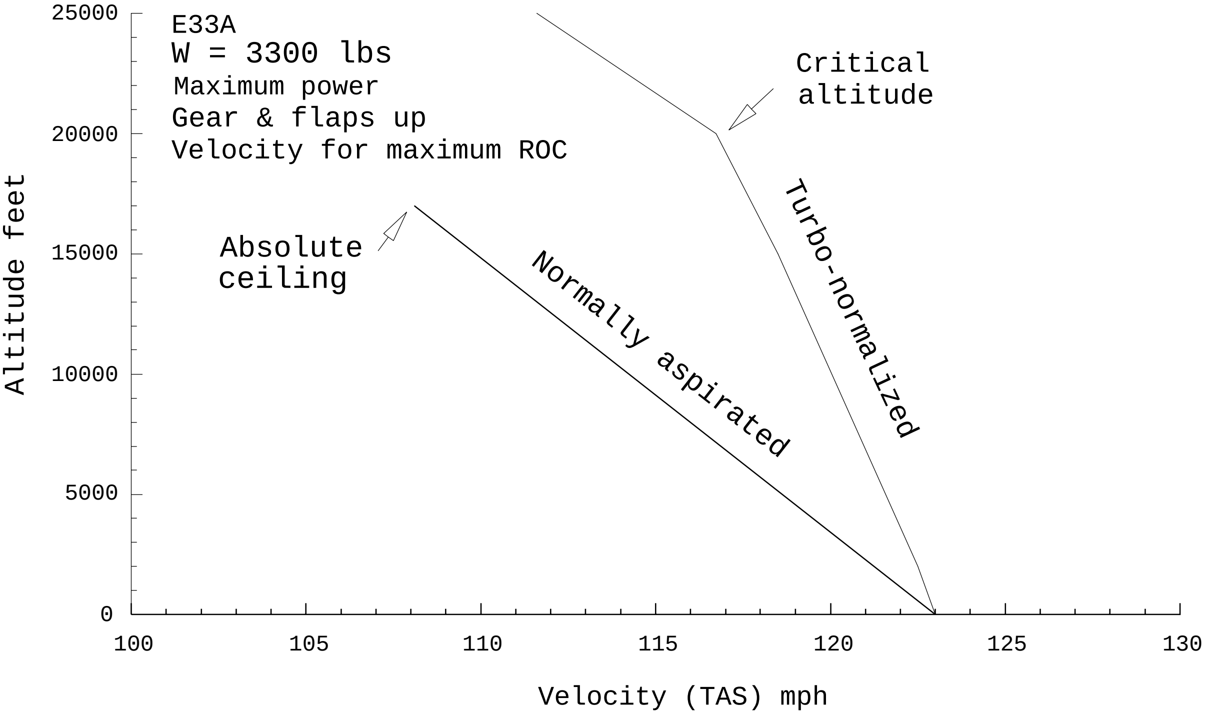

Figure 4. Altitude vs velocity for maximum rate-of-climb.