High-Performance Training

A high-performance airplane has an engine that produces more than 200HP at maximum rated power. Most modern reciprocating high-performance aircraft also have a controllable pitch propeller.
Because the Cessna 180 is a very popular airplane and a good high-performance trainer, these notes will focus on the Cessna 180. The notes are divided into three sections: the controllable pitch propeller, engine management, and high-performance flying aerodynamics. These sections assume the reader is familiar with single engine, fixed pitch propeller airplanes, like the Cessna 172.

Controllable pitch propeller

The main difference between a simple Cessna 172 and the Cessna 180 is the use of a propeller control and manifold pressure to set power. The controllable pitch propeller can also be called a constant speed propeller since the propeller knob (often colored blue) controls the engine RPM at the normal cruise power settings. Once this RPM is set, the prop will continually rotate at this constant speed.
The throttle controls manifold pressure (MP) and pitch of the prop. Increasing throttle increases the manifold pressure (the pressure of the flow of fuelto the engine) and the prop tries to turn faster. The prop controller then resists faster RPM by increasing the "bite" of the blades in the air. This increased pitch and angle of attack of the blades causes more thrust, but also causes more drag, resisting an increase in RPM. In a sense, throttle only increases the torque of the engine, and then the prop governor increases the pitch of the blades to produce more thrust and drag. This happens quickly and automatically, so no change in RPM is noticed.
So the throttle controls the MP/engine torque/prop pitch, and the prop knob regulates engine/prop RPM.

Many modern high-performance aircraft are very noisy on takeoff and landing. Experienced pilots mitigate this problem by avoiding high RPM and oversquare conditions whenever possible. At high RPM on takeoff or in preparation for landing, the prop tips may reach supersonic speeds, causing quite a bit of noise and inefficiency. Some airplane owners replace their two-bladed props with three blades to reduce noise and increase efficiency, since each of the three blades now has an angle-of-attack which is less than for the two-bladed prop.

This is also why pilots avoid oversquare conditions (MP greater than RPM, such as 27"MP and 2200 RPM). At such high torque and low RPM, the blades take a very large "bite", and this high blade angle-of-attack is inefficient or may even cause the blades to stall. Imagine the blades are little wings. At squared power (27" and 2700RPM) the blades are exactly at Vy, best efficiency for climb for time. At oversquare (27" and 2400RPM) the blades may be at Vx, still efficient, but less so than squared. Finally, at severe oversquare (27" and 2200RPM) the blades are in a stall, and they produce negligible thrust (analogous to zero lift of the wing).

In review of the controllable pitch propeller:

- the RPM control (blue knob) sets prop/engine RPM
- the throttle (black knob) controls prop pitch/manifold pressure unlike a fixed-pitch prop, produces max RPM/power for takeoff
- loss of oil pressure causes flat pitch to stops (high RPM)
- lower cruise RPM causes less noise, smoother through turbulence
- prop oil freezes at altitude, alter the prop control every 15 min
- idle throttle causes flat pitch, high drag "plate" airbrake
- 12" causes zero thrust condition, no drag and no thrust
- higher MP with same RPM causes more torque and p-factor
- oversquare settings are inefficient and overtorque the engine

Engine Management

A complexity of high performance engines is power management. A Cessna 172 has a low power, four-cylinder engine, with excellent airflow providing cooling to all four loosely cowled cylinders.
A Cessna 180, on the other hand, has a large, powerful, six-cylinder engine with a moderate size cowling and poor airflow to the middle two cylinders. Dramatic changes in power cause the four outer cylinders to cool much more quickly than the middle two cylinders. This uneven cooling may cause the middle cylinders to warp or crack. This phenomenon is called "shock cooling."
To avoid shock cooling, cowl flaps are open for takeoff to compensate for the low airflow and lack of cooling over the engine at this hot power setting. After takeoff, at 1000 AGL, lower the nose and reduce power to cruise climb for cooling. Leveling off for cruise, the cowl flaps may be placed at half or closed position, depending on power setting and airspeed. Since the engine is kept fairly warm during this whole period, shock cooling is less likely in these stages.
Shock cooling is most prevalent in the descent for landing. A pilot at high cruise may initiate a descent for landing by pulling power to idle, richening the mixture, and pitching the nose down for a fast descent. The engine at low power produces much less heat, the rich mixture provides an excess of fuel to cool the cylinders, and the increased airspeed and airflow further cools the engine quickly.

If a cylinder head temperature (CHT) and exhaust gas temperature (EGT) gauge is installed, the CHT will dramatically drop for the outer cylinders and the EGT for all cylinders will read negligibly. The owner of this airplane will need new "jugs" (cylinders) much sooner than the rated time between overhauls (TBO).
Instead, the experienced high-performance airplane pilot will manage the cooling of the engine by slowly, evenly reducing the cylinder temperatures. The pilot plans for the descent much further away from the destination, planning for a 300 ft/NM descent, starting the descent from cruise at 10,000 feet and 30 NM from the destination.
The pilot pitches down in a gradual descent, which slightly increases airspeed and cooling. To counter this cooling, the cowl flaps are moved from half-open to full-closed to warm the engine.

The pilot then starts a very gradual power reduction, reducing MP by 1" per minute (some pilots do 2" per 2 minutes). As the power is reduced, the engine cools gradually, but the airspeed also slows slightly. This lower airspeed reduces airflow and slightly warms the engine.
The pilot approaches the pattern entry point somewhere around 16" to 18"MP. He may be too fast for the pattern. Instead of reducing the power further, the pilot (counter intuitively) sets flaps to approach setting. Other airplanes (like a Bonanza) may drop the gear, use flaps, or even use speed brakes to increase descent or slow the airspeed when power reductions would otherwise shock cool the engine.
The pilot is now abeam the numbers or on final, at the correct airspeed. Following the checklist, the mixture is set full rich and the prop is set at high RPM in preparation for the go-around. By waiting until the plane was slowed and the power was 15" to 17" before setting the prop, he didn't have a noisy, high RPM prop in this low pattern. As the prop goes forward, the MP drops another inch to 14".
Now the pilot is still a little too high for landing. Instead of pulling power off (far below the RPM green arc), he increases the flap setting to increase the descent rate. He then sets up for landing with 20 flaps and 12" for normal landings, or 10" and 40 flaps for a short field. The lower airspeed on final keeps the engine warmer as the MP is reduced.
Finally, after landing the pilot taxis smoothly off the runway, raises the flaps, and opens the cowl flaps to improve airflow over the engine on the ground. The pilot taxis slowly to the ramp, and shuts down.

In review of engine management:

- use cowl flaps to cool engine for takeoff, half for high cruise
- plan 300ft/NM descents, 10K AGL/30 NM, 1000 AGL/3 NM
- pitch down and close cowl flaps to start descent
- gradually decrease MP, 1" per minute or 2" every two minutes
- if ATC requests descent consider using speed brakes/gear/flaps
- use CHT/EGT/oil temp gauges to monitor engine cylinders

High-performance and high altitude factors

High-performance airplanes can fly at greater altitudes and speeds, but the extra power causes exaggerated flight characteristics at lower altitudes and airspeeds. First, we'll discuss the performance at higher altitudes.
In the altitude "teens," non-turbocharged airplanes cannot consume enough air to continue at full power. Since the plane runs on a fuel-air mixture, the thinning air combined with the still unchanged flow of fuel causes the engine to run too rich. This is why the plane must be leaned as altitude increases. With this leaner mixture, both less air and less fuel are available, and the maximum horsepower available at max throttle gradually decreases.
The fairly expensive alternative to this is turbo charging. Turbochargers compress air and then mix it with fuel. Such a condensed mixture may provide more than 30" or 40" of manifold pressure, even up to the flight levels (although there are limits to turbochargers as well). This allows the airplane to fly at much higher altitudes.

The benefits of flying high are threefold. First, winds are stronger so that flying west to east, the lower part of the jetstream may provide a 50 to 100 knot tailwind. Second, most weather and much turbulence are at 12,000 feet and below and can be avoided. Third, the true airspeed (TAS) increases with altitude, so that in still winds, the plane flies at a faster groundspeed at altitude for the same power setting. Most pilots use this fact not to fly faster, but to reduce fuel consumption at the same TAS.

For example, the Aero Commander 560 flies at 190MPH at 80% power at sea level. At 15,000 feet, the same airplane flies at 190MPH TAS using only 60% power. The difference is 25 GPH vs. 39 GPH, or 14 GPH (about $30 an hour). Fuel consumption can be 50% more for the same speed at sea level, quite a difference. However, the additional fuel used to climb may be significant, so flying high only saves fuel for longer trips.

The disadvantages of flying high are freezing temperatures (for the passengers and the prop governor) and hypoxia. Oxygen and a good cabin heater help. For medium-leg flights, flying at 11,500 or 12,500 is fine. For longer flights, 14,000 and 15,000 are fine with just the pilot on a nasal canula. Slightly cold and with little oxygen, passengers and kids get quiet, sleepy, and are less prone to motion sickness. This is why the airlines keep the cabin a little cold and at 10,000 feet pressure altitude. As long as the pilot uses oxygen, stays awake, and moves the prop control occasionally, the disadvantages can be minimized.

High-performance aerodynamics come into play at lower speeds during takeoff, go-arounds, and landing. A Cessna 180 produces a lot of power and airflow on takeoff, with significant torque and p-factor, as well as strong effectiveness of airflow over the aileron trim, rudder trim, and flaps. If these are not set correctly for takeoff or go-arounds, a pronounced nose-up pitch and possible spin may result. This is very common when the center of gravity (CG) is at the forward limit.

Because of the forward CG, as power is reduced for landing, the nose is trimmed full up. With no engine power or accelerated slipstream over the horizontal stabilizer, the plane is trimmed for level landing or slight nose up. Unfortunately, if a go-around is initiated or the plane is not retrimmed for takeoff, when the airflow from the engine is increased to full, the elevator trim pitches the nose up greatly – perhaps exacerbated by flaps also pitching the nose up. This is a classic trim stall.

Awareness of the forward CG and prevention of trim stalls is important. By landing with some power on, using minimum flaps, using minimum power slowly applied for go-arounds, making landings to a full stop, using checklists, and loading for middle CG, an average pilot can avoid trim stalls or nose-first / porpoise landings.

<u>In review of high altitude and high performance factors:</u>

- fly high at low RPM for low fuel consumption
- be aware of freezing temperatures and hypoxia at altitude
- trim for CG is dramatic; with full power, trim may cause a stall
- accelerated slipstream with high wing flaps may cause a stall
- torque and P-factor are higher; rudder trim for extended climb
- load the plane for middle CG to avoid nose-first arrivals
- use some power (12"-15") for landing elevator effectiveness