These pages were taken from the Airplane Engines manual at PilotWorkshops.

Airplane Engines

A Pilot-Friendly® Manual

How to get the most performance, dependability, and longevity from your engine.

Check Engine Instruments on Runup

Too many runup checks are done by rote. The pilot flicks the mags switches, pulls the carb heat on for a moment, and—hopefully—checks the other engine gauges. This is partly because we don't teach what to watch for except an excessive RPM drop that shakes the airplane enough the iPad falls off the glareshield.

We can do better. The biggest place for improvement is the so-called "mag check." Let's start by calling this an "ignition check," because it's really checking the whole ignition system: magnetos, wiring harnesses, spark plugs, and the ignition control switch (key). When checking the ignition, slow down. Rushing the check can hide important information, especially if you have an engine monitor installed.

Once you've set your runup RPM with both mags still on, look at your EGTs on the engine monitor. Ideally, they are close to equal but they won't be perfect. The important part is the shape of the graph. When you disable one of the two magnetos, all the EGTs should rise but the shape should stay roughly the same. Another option is to use the normalize mode (page 50), if available. This better reveals the relative rise (or fall) of EGTs and even changes the scale on some systems so differences are easier to see.

Note your current CHTs. These should change very little during the ignition check, other than maybe to rise a little and uniformly as the engine warms up a bit.

Disable the left magneto by turning the ignition key to the "R" position. (See "Make it a habit: Check Right first" on page 29.) Wait for the RPM to stabilize. In almost all cases, one of four things will happen and they mean different things.

TIP

Don't obsess over RPM. If your POH says 1700 RPM, but you prefer 1800, that's fine. Just make it high enough to test engine and accessory output, and be consistent. That said, don't let a digital tach make you crazy. Running up at 1700 RPM means anything from 1650 to 1750. Just note the starting point so you know the relative RPM drop.

MAKE IT A HABIT: CHECK RIGHT FIRST

Many instructors have taught their students to test the ignition by first selecting the right mag (two clicks from both), then back to both, then the left mag (one click from both), and then both mags. This is a good habit, as it prevents you from testing the right mag and then accidentally selecting only the left mag to finish the check.

1. Expected Drop and Smooth

Hopefully, the RPM drop will be within the allowed amount and the engine will run smoothly. Most pilots stop there, and that's a mistake if you have an engine monitor.

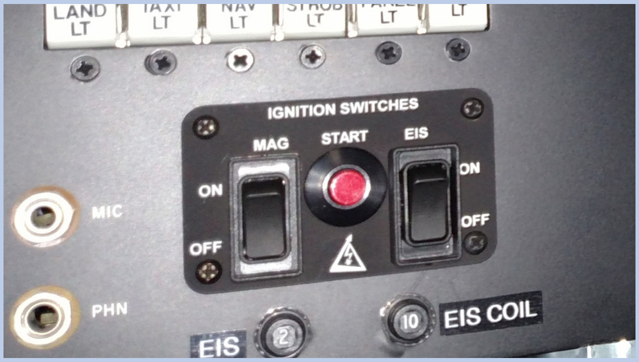
With the ignition still on the right mag, check that your EGTs have all risen and the shape of the distribution is roughly the same. The EGTs rise because the single spark is less effective at initiating the combustion, so the fuel is burning for a longer period of time and further into the cycle of the piston. The exhaust gases have less time to cool before exiting the cylinder and passing by the EGT sensor.

Any EGT *falling* is a sign that the active spark plug in that cylinder (the one driven by the right mag) is not performing correctly. This usually creates roughness, but not always, especially with six-cylinder engines.

If this happens, attempt to clear a fouled plug (page 33) and then test running on only the right mag again. If you still see the problem, then you'll need to troubleshoot back at the ramp. It's probably a fouled plug, but the problem could be in the wiring harness to that plug, or that terminal on the magneto. (See "Create a Mag-to-Plug Chart" on page 31 for a tool that'll help in finding the problem plug quickly.)

CHTs should stay steady or show a slight drop while running on one mag. If you see all the CHTs trending downward, see how much they drop over the next minute or so. Note the drop, because there could be a problem but you won't know until you check the other magneto (hold that thought).

RUNUP WITH SOLID-STATE IGNITIONS



If you have electronic ignition replacing a magneto (page 119) or a Rotax engine, the ignition checks obviously change. Dual electric systems with a carbureted Rotax typically do show a drop when running on one module. Electric engine controls such as the injected Rotax or some aftermarket magneto replacements often show no drop. However, they will show an error (hopefully with a code) if there's a problem.

2. Excessive Drop and Smooth

An excessive RPM drop with a smooth running engine, and a rise in all EGTs, is likely retarded timing in the magneto that's still running (the one selected with the key/switch). This robs you of total engine power, so it should be checked by a mechanic. Before you taxi back, first check for an expected drop and smooth operation on the other mag.

3. Rough Regardless of the Drop

Roughness almost always denotes an uneven power distribution. Your first step is to check the EGTs. If they have all fallen, this is likely a magneto problem. It could have such retarded timing or an internal problem that combustion is failing intermittently throughout the engine. That's unusual, but possible.

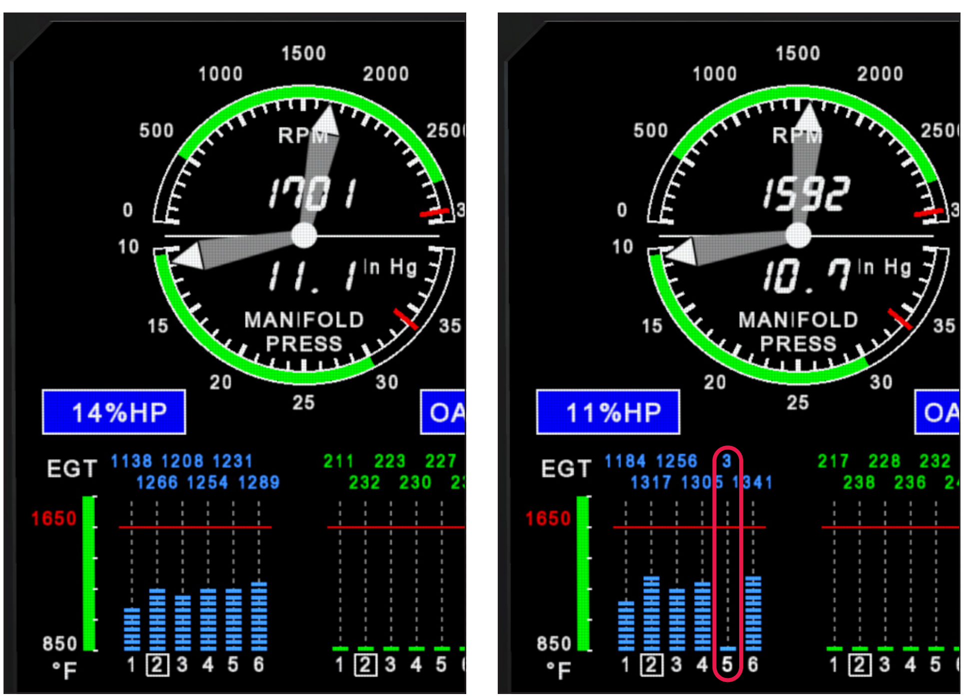
Much more likely is a problem with the ignition in specific cylinders. Look for the cylinder(s) with an excessive EGT drop. It may even be dropping off the bottom of the scale indicating that no combustion is happening there on the offending mag. Your first task should be to clear a fouled plug (page 33). If that doesn't work, go back to the ramp with your mag-to-plug chart in hand for troubleshooting (page 31).

4. An Absence of Change

No change at all: No RPM drop and no EGT rise is probably the switch itself, or some other part of the ignition grounding system, so test that (page 39). If it is, follow the procedure to troubleshoot exactly where the fault lies. Remember that the mag stays hot so hands off the propeller and keep that area clear at all times.

However, if there's no drop and grounding works, there's a much more dangerous possibility. Little or no RPM drop combined with little or no EGT rise could also be advanced timing on the current mag. It's even more likely if you saw CHTs on the other mag dropping significantly.

The timing of the spark for normal airplane magnetos is the same regardless of engine speed. This means it's only optimized for maximum RPM where getting the most power is critical. The spark ignites the fuel at just the right time so the burning



A relatively normal EGT spread with both mags on (left) clearly reveals a problem is in cylinder 5 on only the right mag (right).

flame front and expanding hot gases meet the top of the cylinder just as the piston is descending. If it arrives too late (retarded timing), the engine won't produce full power. If it arrives too early (advanced timing), however, the pressures inside can rise to damaging levels and the CHTs can go off the charts. If it's really off, engine failure can occur in minutes.

If you ever see a situation like this after any engine maintenance, taxi back to the ramp and get the timing rechecked. None of this applies to electric ignition where you might normally see little to no drop on the runup test (page 30).

You'll learn the details of your system over time, and that's its own check. You want consistency between the two ignition systems on any check, and from flight to flight.

CREATE A MAG-TO-PLUG CHART

Suppose you get a rough engine when running on the left magneto and the EGT for the cylinder 4 plummets. You have a problem with a spark plug or spark wires to that cylinder, but it could be the top plug or the bottom one. Save yourself or your mechanic some time by having a chart showing which mag powers which plug on each cylinder. Then the offending plug can be checked for fouling that you couldn't clear from the cockpit (page 33) without hunting around.

Cylinder	1	2	3	4	5	6
Right Mag	T	B	T	B	T	B
Left Mag	B	T	B	T	B	T

You'll need to take the cowling off to follow the wires. Most engines are set up so each mag controls the top plugs on one side of the engine and the bottom ones on the other. When you map this, double check that the P-leads that ground the magnetos go to the correct position on the ignition switch. There's no way to tell if they're reversed in regular operation. Testing this will require a multi-meter or your mechanic's help.

If you don't have such a chart, you should try removing the bottom plug first, as that's the one more likely to foul. If you don't have an engine analyzer, you won't know which cylinder it is unless you do the old-school "pen test." Taxi back to the ramp on the mag that makes the engine run rough (presuming it's not so rough it may cause damage) and find a plastic pen you don't care about. Shut down and quickly de-cowl the engine. Touch the plastic to each cylinder exhaust stack right at the cylinder. One of them should be cold and not soften or melt the plastic tip. Spitting on each cylinder might also work. Listen for the sizzle.

Carb Heat: Real Drop; Alt Air: No Drop

Many POHs simply say "RPM drop" as what to look for when turning on carb heat. You should check to a more exacting standard.

Application of carb heat should produce 100-200 RPM drop at runup, depending on the engine. Too little could be an indication of fresh air leaking into that system (drawing in cold air with warm) or incomplete closing of the carb heat door (carb heat always partially on). It could also indicate a partially blocked air filter. In that case, you see a small RPM drop with carb heat because your primary air intake is robbing you of power all the time.

How little drop is too little? Every engine is different, but if you see less than 100 RPM, ensure the system is working as designed. (There are some engines, like the O-320 in some mid-70s Cessnas, that normally see only 50-75 RPM drop.)

Check that the carb heat knob is still at least an eighth of an inch from the panel when the knob is all the way in (carb heat off). This helps ensure the door is fully closed before you run out of cable length pushing it closed. If the system checks out, then know your airplane exhibits a lower than average drop. The key is knowing what you should see, and seeing it every time.

Carb heat doubles as a backup air source for your engine in case the filtered air system gets blocked. Fuel-injected engines have an alternate air source for this role, but there should be no drop in RPM when it's tested. If you ever see a substantial *rise* in RPM when testing alternate air, it may be time to change your air filter (page 104). Many alt air systems are automatic, so there's no runup check for them.

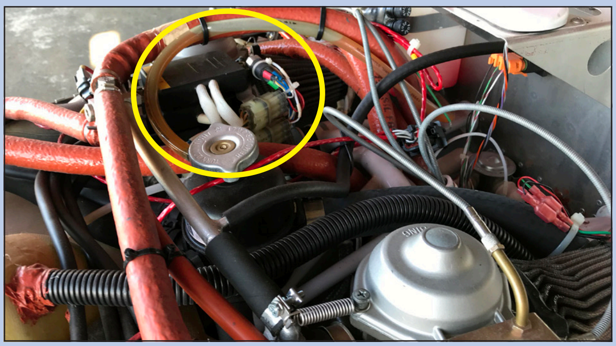
While you're at it, if you have a standby vacuum or backup alternator system, think about checking

ROTAX LOOSE CONNECTIONS

Rotax engines can vibrate a lot, especially the carbureted ones if the carbs aren't well balanced. That's usually worst at low RPM and gets smoother as RPM increases.

However, a strong vibration when running on only one ignition system is often a loose connector to the ignition module. If you're doing a carbureted Rotax runup and this happens, taxi back to the ramp and shut down. Remove the cowling (page 84) and set it aside.

Find the two ignition control modules on the top of the engine. Each one is about the size of a deck of cards. Squeeze together tightly on the plastic wire connectors to make sure they have good contact. Start up and try the ignition test again. Hopefully, it's smooth on each system now.



this with your carb heat or alternate air before any flight at night or in IMC. The whole point of these systems is that they jump in when the primary fails, but that's only if they didn't fail months ago and you never noticed. Checking standby systems the same time you check carb heat (or some other common runup item, like loading the electrical system) builds a good habit.

If you have carb heat, ensure the carb heat knob still has a bit of clearance to the panel when you can't push it in any further. This helps ensure the flapper valve behind the panel has fully closed.

Engine Gauges in the Green

For the most part, other engine indications simply showing their normal range during runup is adequate. Every engine has its own quirks, and you'll see variations with the outside temperature or even the grade of oil used (page 112). Perhaps the most important things to track as a pilot/owner are the trends over time. Once a month or so, jot down the values you see on a notepad, or download the engine data (page 78) and verify that no values are consistently moving away from the norms.

One misunderstood area is the load test for the charging system. You should ensure it can support recharging your battery and supplying power to everything you might turn on, at the same time. The best way to test is usually to turn everything reasonable on: All the lights, pitot heat, prop heat, etc. Messy items like deice fluid pumps can be left off, and obey any prohibitions for hot items on the ground, such as windshield heat.

You might consider extending electric flaps at this point, but please don't start the flaps moving and then reverse their direction with the switch before they stop. This can cause damage. Let them stop moving before repositioning them for takeoff.

While the system is under load, check the voltmeter and ammeter. System voltage shouldn't drop out of range. Current draw should show still charging the battery (except for a momentary discharge during a strobe flash, for example) or no more load than the alternator rating (with a load-meter type gauge). If your charging system can't supply maximum power without the battery helping, get that checked out.

Remember that normal voltage for a "12-volt" system is usually 13.5–14.5 V when the alternator is working. For a "24-volt" system, it's usually 26.5-28.5 V. Ask your mechanic if unsure which you have.

Be careful about readings "slightly out of the green." A slightly low vacuum could be a leak that will worsen, or a regulator going bad that could eventually damage an instrument. Slightly off oil or coolant temps could be a winterization kit that someone forgot to remove when the weather turned warm.

The onset of carb icing in the real world is usually subtle. You will lose power, showing as decreasing RPM with a fixed-pitch prop or decreasing MP with a constant-speed prop. Because you're probably in level flight, you might first notice decreasing airspeed.

The typical reaction is simply to open the throttle a bit more, which only masks the problem. If you're flying a carbureted airplane, ask yourself when you reach for the throttle, "Is there any chance I'm picking up a little carb ice?"

Apply it Proactively

Carb heat is much better at preventing carb icing than removing it. Hence the proactive use in the traffic pattern and for low-power airwork we learn as students. If you have any reason to suspect that carb ice is forming—or are worried it might form—apply full carb heat. Carb heat is unfiltered air, but this shouldn't be a concern once you're higher than pattern altitude.

If you lose more power than normal, or the engine runs rougher than normal, the ice might have already started. There's only one catch to this: Most pilots have no idea how much impact carb heat has on normal operations, so "lose more power than normal" has no meaning.

So that you don't fall into that category, apply full carb heat in cruise a few times at various power settings. Note the average power loss and engine feel. Use that as a baseline. You'll need to do this a few times because it's possible one of those times you had some ice and didn't know.

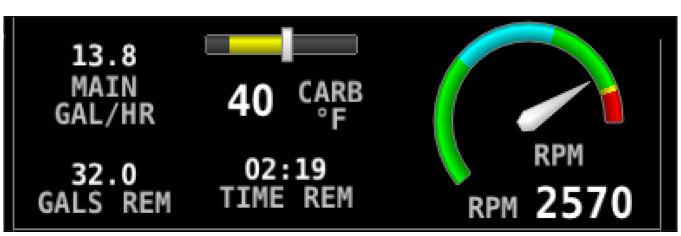
Because the incoming air is hot (often 130°F or more), it's less dense. That's like operating at a higher altitude, so the engine will generate less power. It will also run richer, so you'll have to lean for cruise (page 46) again. Few carbureted engines will run LOP, so your mixture probably got further on the rich side of peak. If that's true there's no big hurry to re-lean. If you're one of the lucky few who run LOP with a carburetor and you apply carb heat, adjust the mixture leaner as soon as practical ... or switch to ROP operations. Hotter intake air also provides less

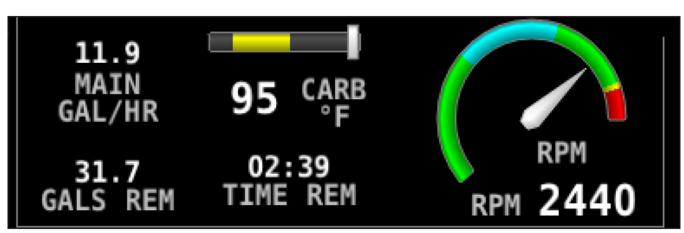
WHY CARBURETOR ICE FORMS

There are two reasons the temperature drops in the carburetor: The pressure drop in the venturi has a corresponding temperature drop and the atomization of fuel absorbs heat. The two factors together make the throat of a carburetor a cold place.

Moisture coming into the carb can supercool, which allows it to freeze on impact with the carb venturi or throttle plate. The next droplets freeze when they hit the first ones and so on. The more the throttle plate is in the way of incoming air (lower power settings), the more area there is to hit and freeze. Even if there isn't visible moisture, the temperature drop could be great enough to cause condensation. If the temperatures are so low the moisture fully freezes before striking a surface, it won't stick and build up. Carb heat both reduces the likelihood of reaching a supercooled state, and increases the temperature-dewpoint spread so condensation is less likely to occur.

Cars rarely saw carb icing because the carbs are usually on top of the engine where they stay warm. Airplane engines must have the crankshaft as high as practical for propeller clearance, so they are essentially built upside-down with the carbs underneath.





A carb temp gauge lets you see when you're in the danger zone (yellow band, left) regardless of power setting. It also means instead of applying full carb heat and taking a huge performance hit (right), you can apply just enough heat to stay out of trouble.

WHY DO CESSNAS CALL FOR CARB HEAT BUT PIPERS DON'T?

The Continental O-200 powered Cessna 150 is notorious for carburetor icing issues. The same basic airframe of the Cessna 152 with a Lycoming O-235 isn't. Cessna 172s with a Lycoming O-320 recommend carb heat for extended low power, such as the traffic pattern. Piper Cherokees with the exact same engine recommend carb heat only when icing is suspected.

Maybe it's the difference in their cowlings and the position of the carb relative to the chosen exhaust system in each airplane. Maybe it was the legal department. The real takeaway is to know how your airplane behaves and plan accordingly.

margin against detonation (page 60). This should only be a problem for high-power engines operating at 75 percent power or more, but it's worth noting. If you must use carb heat during climb or high-power cruise, err to have extra fuel cooling and watch your CHTs closely.

Carb heat pipes hot air from around the engine exhaust, so it works best at cruise power and is less effective at lower power—which is exactly when carb ice is more likely to form. Again, apply carb heat preemptively if you suspect it might be a problem.

When is it likely to be a problem? Given that the temperature drop inside the carb can be 60°F, you'd think any time the dewpoint is within 60°F of an air temperature under about 90° it would be possible. This is why people have been surprised by carb ice in clear air on cloudless days. Certainly, the more likely days are when temperatures and dew points aren't that far apart or have actually met because you're flying IMC.

Use Carb Temperature Data

Many aftermarket engine monitors offer carb temperature gauges that measure the temperature where the ice actually forms. This is a terrific proactive tool. If the carb temperature is in the icing zone, add just enough carb heat to bring the temperature out of that zone. Without the temperature gauge, conventional wisdom is to only apply full carb heat or none, so you don't accidentally put the carb temperature in the icing zone. This may be true, but real evidence of this as a problem is spotty at best.

If you're flying at cooler temperatures in clouds where there's lots of moisture, observing that the carb temperature is actually below the zone where icing is a problem is reassuring—and would prevent you from adding carb heat only to bring the temperature up to a point where it's an issue. The carb temperature gauge is also a great way to see that your carb heat is working on runup (page 29).

Because carb heat bypasses the air filter, it can keep your engine running if the air filter becomes partially (or completely) blocked. This is why carb heat is on the checklist for total power loss. If you have so much carb ice the engine has quit, it's not going to clear before you glide to the ground, especially given that its source of heat (the hot engine exhaust pipes) is rapidly cooling down. Fuel-injected airplanes that don't have carb heat still have an alternate air source for this reason.

Applying carb heat can also improve fuel distribution by better atomizing the fuel. This can make a rough engine run smoother, or even allow for LOP operations in some big carbureted engines. This practice is favored by some Cessna 182 and 195 owners, whose engines have notoriously terrible fuel distribution. It should only be done with a carb air temperature gauge to keep carb icing at bay as you experiment with various amounts of carb heat.

Finally, if you suspect your airplane runs too lean at idle, apply full carb heat while idling and look for a rise in RPM instead of a drop. If you can't aggressively lean for taxi (page 24), or the engine just won't idle well below 1000 RPM, this is worth checking.

TIP

Those flying fuel-injected engines can simply skip this task. Those flying Rotax engines with carburetors can probably also skip this task as few Rotax installations have carb heat. The position and style of the carbs used by Rotax make carburetor icing unlikely, unless you're flying in IMC.