The Proficient Pilot

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Chapter 20 **How to Interpret Engine Instruments**

In our increasingly complex society, many more people are breaking down under stress than ever before. Aircraft engines obviously are not subjected to psychological pressures, but they do have equally critical limits that must not be violated. Otherwise, they too, can fail.

Fortunately, engine-operating limits are defined precisely, usually displayed as green, red, and yellow instrument markings (not always, in older aircraft). But not all of these radials and arcs are understood. (And not all of the instruments are as accurate as they should be.)

Consider, for example, the green arc on the manifold pressure (MP) gauge. This represents the normal operating range. But what is the significance of the low end of the arc (usually about 15 inches of mercury)? When developing power "within the green," the engine powers the propeller. But when "below the green," it usually is the windmilling prop that drives the engine.

Prolonged operation below the green can be as detrimental to the engine as rough and rapid throttle action. This is because crankshaft counterweights (designed to dampen engine vibrations) may become erratic and detune the engine. The results are increased vibration and internal wear, which lead to reduced engine life, more expensive overhauls, and in some cases, powerplant failure.

For the same reason, a simulated engine failure should be induced by fully retarding the mixture control and leaving the throttle open. This allows manifold pressure to remain high and keeps the combustion chambers filled with a supply of shock-absorbing air. Prior to rekindling the engine, slowly retard the throttle. Then advance the mixture control and allow the engine to warm.

The upper limit of manifold pressure for normally aspirated (nonturbocharged) engines is 30 inches. But rarely can this much be achieved. That is because of induction losses from restrictions to the flow of intake air such as filters, bends in the plumbing, and the throttle valve itself. The typical engine at sea level can develop only 28.5 to 29.5 inches MP at full throttle. Readings much below these values may be indicative of trouble and should be investigated.

Exceeding the maximum allowable MP of a turbocharged engine is called overboosting and is destructive. But, according to Textron Lycoming, a momentary overboost can be tolerated as long as rated manifold pressure is not violated by more than 3 inches for no more than five seconds. Such an overboost may occur when applying takeoff power, as the turbocharger controller "overshoots the throttle." A 5-inch overboost for ten seconds or less suggests an engine inspection; up to 10 inches (for any period) warrants disassembling the engine. Exceeding 10 inches requires overhaul and crankshaft replacement. Teledyne Continental offers similar advice but in some cases imposes more conservative limits.

Pilots are taught to reduce power by first retarding the throttle and then reducing rpm. This is because a combination of high manifold pressure and low rpm can induce damaging detonation. But this does not mean that MP never can "exceed" rpm (28 inches and 2,600 rpm, for example). This does, after all, occur during every takeoff from a low-elevation airport. A rule of thumb for nonturbocharged engines is that detonation can be avoided by not allowing MP to exceed rpm by more than "four" (28 inches minus 2,400 rpm, for example, equals four).

Since high propeller rpm is responsible for most after-takeoff noise, there is nothing wrong with a slight rpm reduction prior to throttle retardation, as long as the rule of four is not violated. It is a handy technique to use when a pilot wants to soften his noise footprint but cannot justify a significant power reduction. This suggestion, of course, does not supersede advice to the contrary published in the airplane flight manual.

The red line on a tachometer indicates more than the maximum-allowable rpm; it also represents the rpm required to obtain the engine's rated horsepower. This illustrates a significant difference between constant-speed and fixed-pitch propellers. With a constant-speed prop, engine rpm can be increased to the red line while the airplane is motionless. In other words, the engine can develop rated horsepower without any airspeed whatsoever. But the maximum-obtainable static rpm of an engine with a fixed-pitch propeller may be as much as 400 rpm below the red line. In other words, such an engine cannot develop rated horsepower during a full-throttle runup. This explains why an airplane equipped with a constant-speed propeller has better takeoff performance than a similarly powered airplane equipped with a fixed-pitch propeller. (As the latter airplane accelerates along the runway, rpm and horsepower steadily build, because increasing airspeed aerodynamically unloads the propeller.)

During the pre-flight runup, pilots can do more than check the magnetos to determine engine health. When operating a constant-speed propeller, learn what manifold pressure to expect at runup rpm. Excessive MP at a given rpm, for example, could indicate a failed cylinder. A full-throttle runup of an engine with a fixed-pitch propeller is not a bad idea (unless pebbles are under the aircraft); this proves whether an engine is capable of developing the expected static (aircraft motionless) rpm. Something is wrong, for example, if the engine of a Cessna 152 cannot develop 2,280 static rpm (the red line is 2,550 rpm).

Exceeding the red line of the tachometer is called overspeeding and can accelerate the wear of stressed engine parts. If allowed to occur frequently, the engine or the propeller could fail. Some propellers have critical rpm limits very close to the red line. So, in some powerplant/propeller/airframe combinations, the propeller is more subject to failure than the engine.

Overspeeding a constant-speed propeller usually is caused by a malfunctioning propeller governor. But a momentary overspeed may occur when the throttle is advanced rapidly for takeoff. This is caused by the reaction time of the governor and usually is not serious if rated rpm is not exceeded by 10 percent for more than three seconds. If the overspeed lasts for more than three seconds, an engine inspection and possible maintenance may be warranted. An overspeed that exceeds 10 percent of rated rpm for any period of time probably justifies an engine overhaul. Tachometers, which often indicate excessively high or low, should be periodically checked for accuracy.

Overspeeding a fixed-pitch propeller is equally serious and is caused by an excessively open throttle at too high an airspeed. An overspeeding propeller also loses efficiency and therefore produces less thrust. This loss is caused by cavitation, compression of air at transonic tip speeds, and other factors.

Pilots should avoid continuous operation within the yellow band of a tachometer, a restriction imposed on a few aircraft (the Mooney M20F, for example). This caution range is not a characteristic of the engine, but of the engine/airframe. While flight testing a new airplane, the manufacturer may detect a harmonic or resonant vibration within a usually narrow range of rpm. This not only is uncomfortable, but could induce metal fatigue (and possibly failure) of a structural member, if allowed to continue for long periods of time.

The first instrument to be given serious attention after engine start is the oil-pressure gauge. Everyone knows that insufficient pressure after 30 seconds of engine operation mandates an immediate shutdown because of possible damage resulting from insufficient lubrication.

A problem not often considered is excessive oil pressure, a condition that may develop after starting an engine with very cold oil. The pressure should decrease to normal, however, as the oil warms. If it does not, the problem might be caused by an improperly set pressure-relief valve (easily adjusted by a mechanic) or oil of the wrong viscosity. In either case, takeoff should be postponed until the difficulty is resolved. Excessive oil pressure can strain the weakest link (sometimes the oil cooler and its hoses) to the point of rupture, at which time the oil simply gushes overboard.

For similar reasons, power should be kept at a minimum after engine start until the oil is warm. Otherwise, powerful oil-pressure surges within the engine can cause damage. An excessive in-flight oil pressure indication probably is caused by an instrument malfunction. But the problem could be caused by an oil restriction in the engine. The pilot should try to decrease the pressure by operating at a reduced power setting.

One of the most traumatic in-flight indications is the total loss of oil pressure. Although this could be caused by a failed gauge or an obstruction in the pressure-relief valve, experts agree that it usually is caused by an insufficient supply of oil. They advise that, although engine instruments are not very accurate, they rarely fail. So if the pressure drops to zero when flying a single, believe the indication and quickly find a place to land. When flying a twin, shut down the ailing engine before it self-destructs. (Most engines develop oil pressure with as little as two or three quarts.)

Some textbooks claim that an engine malfunction, such as a loss of oil pressure, can be confirmed by an abnormal indication of another instrument. But this is not necessarily true.

If an engine loses oil gradually, there might be a slight increase in oil temperature. But if the loss occurs rapidly, such as when an oil line ruptures, there may be insufficient time for an oil-temperature rise to register prior to engine failure. When all oil pressure is lost, there actually may be a decrease in oil temperature, as oil ceases to flow past the temperature-sensing probe in the engine.

Similarly, cylinder-head temperatures (CHTs) may rise slightly in response to a rising oil temperature as oil quantity slowly dips below a marginal level. But if oil is lost rapidly, there probably will not be a noticeable rise in CHT.

A pilot should not rely on other indicators to confirm the total loss of oil pressure. Nor will he have much time to ponder the problem. An engine operating at cruise power and without oil probably will seize (due to extreme friction) in about 30 seconds. Although the prop will come to an abrupt standstill, the shock poses no threat to the engine mounts or the airframe. But do plan on buying a new engine.

Noticing a loss of oil pressure, a pilot should reduce power as much as practical to prolong engine operation. At idle, for example, the engine might continue to run for 5 to 15 minutes, depending on engine condition. This gives the pilot of a single some time to find a landing site and possibly have a few seconds of reserve power available for emergency use.

Does a fluctuating oil-pressure needle signify an imminent loss of pressure? Probably not. This usually indicates either a malfunctioning gauge or an improperly seated, thermostatic-bypass valve, an easily corrected problem.

In addition to lubricating an engine, oil also is used to carry heat away from the cylinders and to help keep an engine relatively cool. But if oil temperature is allowed to become excessive, the oil loses much of its cooling ability. This allows cylinder-head temperatures to rise and increases internal wear. Excessive oil temperature sometimes can be confirmed by a slight reduction of oil pressure.

Hot oil and cylinder-head temperatures do not always occur simultaneously, however. The early-model Cessna Cardinal, for example, had an unsatisfactory oil cooler but a very effective cowling and baffle system. Consequently, it was not unusual to notice a high oil temperature and only a moderate CHT.

Excessive oil temperature during a climb is best countered by reducing power and leveling off, increasing airspeed. After the oil cools, resume the climb until the temperature again nears unacceptable limits, and repeat this procedure as necessary. This is known as step climbing.

Cold oil, of course, is incapable of providing sufficient lubrication and can generate destructive pressure surges that do not register on the oil-pressure gauge. This is why an engine should not be allowed to develop significant power before the oil has had an opportunity to warm. Common knowledge? Of course. Then why do so many pilots allow cold engines to start with a roar and apply breakaway power to jump a tiedown cable before the oil-temperature needle has been given a chance to move from its place of rest? Such mistreatment accelerates wear and increases the likelihood of failure.

To discourage this kind of abuse, some airframe manufacturers offer more precise advice. Beech Aircraft, for example, warns not to allow the engine of a V35B Bonanza to exceed 1,200 rpm until the oil temperature rises to 75 degrees F.

Oil temperature, of course, should be "in the green" prior to takeoff. But what if the indicated temperature fails to rise after a normal runup period? Unless the oil is cold-soaked because of frigid outside air temperatures, the gauge probably is at fault. At such a time, a takeoff is permissible as long as the engine does not balk at full throttle and the airframe or engine manufacturer does not prohibit it.

High power settings also should be avoided until cylinder-head temperatures have warmed sufficiently. Otherwise, a takeoff could scuff and damage rings, pistons, and cylinder walls.

Excessive head temperatures must be avoided because they are the most likely cause of detonation and preignition. Although a high CHT often is accompanied by correspondingly high oil temperature, do not count on seeing such a verification. Broken or missing baffles can cause high head temperatures without affecting oil temperature.

Excessive cylinder-head temperatures often are caused by a slow-speed climb on a hot day. When this occurs, rising temperatures can be held in check by patiently step-climbing to altitude.

An increasingly common cause of high CHTs is excessive leaning—a probable result of high fuel prices. Fuel may be expensive, but replacement pistons are more so.

The CHT gauge measures the temperature of what is considered to be the "hottest" cylinder, determined by the airframe manufacturer during the flight testing of a new aircraft. Theoretically, therefore, other cylinders are cooler than is indicated by the gauge. But it does not always work this way in practice.

Uneven fuel distribution (in carbureted and fuel-injected engines) can cause any of the cylinders to be the hottest at any given time. So while the CHT gauge indicates something less than the maximum-allowable temperature, another cylinder could be overheating and detonating without the pilot knowing it.

To combat this problem, be very conservative about head temperatures. A better solution is to install a multiprobe, cylinder-head or exhaust-gas temperature gauge. With such instrumentation, the pilot can determine the hottest cylinder at any given time.

Speaking of cylinder-head temperatures, consider applying this suggestion when a faulty magneto is discovered during runup: turn off the good magneto and operate the engine only on the other for several minutes while returning to the parking area. Immediately after shutting down the engine, open the cowling and feel each cylinder head (carefully!) with the palm of the hand. If the magneto problem is caused by a faulty spark plug, one relatively cool cylinder will be felt. This quickly identifies the faulty plug and saves having to remove and inspect the others.

There is nothing particularly serious about excessive fuel pressure or fuel flow, but this could cause a rough-running engine. Resolve this problem by leaning until the roughness is eliminated.

Low fuel pressure usually is caused by a failing pump or vapor lock. In either case, turn on the auxiliary fuel pump.

Fortunately, modern aircraft engines are remarkably tolerant of abuse and neglect. But their reliability is dependent upon our respect for their limitations. Otherwise, like us mortals, they too can yield to the stress and fail.