Proper monitoring of your engine's vital signs can keep you flying safer and longer

Those Engine Gauges

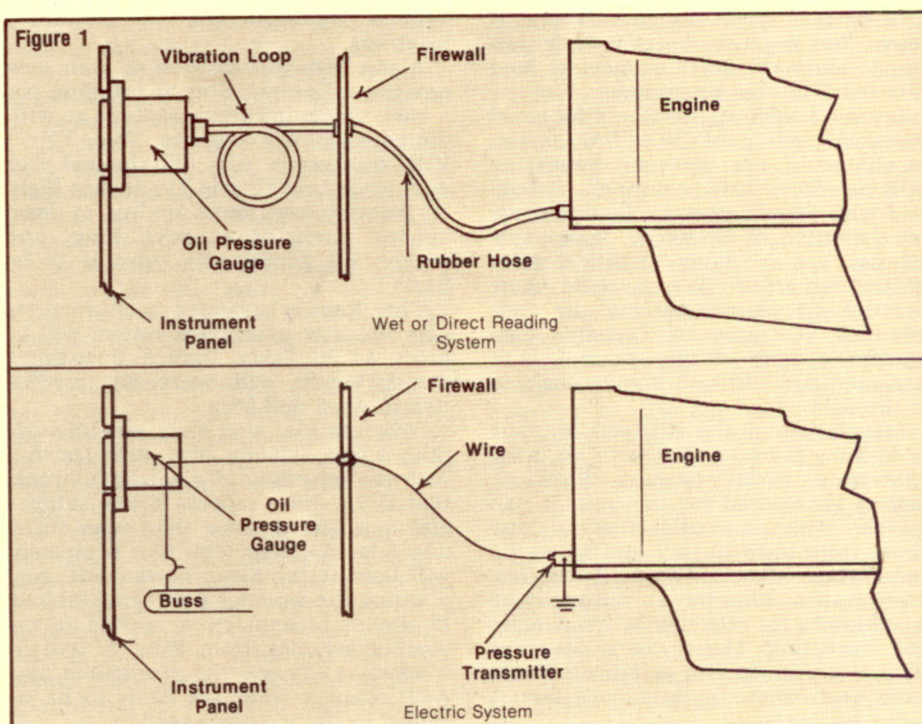
by KEN GARDNER / AOPA 132319

■■ In the automobile's earliest days it had few if any engine instruments. But, it wasn't long before those early builders realized the value in providing the motorist with a timely warning if the vehicle's normal operating vital signs were going awry. Eventually an adequate complement of instruments accoutered the vehicle's dashboard.

The prudent motorist became knowledgeable about these instruments and the information they could provide. The benefits were often prevention of costly engine damage or of becoming stranded along the way. Nevertheless, such instruments add cost to the vehicle and are of questionable value if the motorist doesn't understand their indications or never looks at them. Thus reliable instrumentation gave way to simple warning lights or, as the more discriminating motorist calls them, "idiot lights."

The airplane has had engine instruments almost from its beginning. Despite being difficult to see because of their remote location on some present-day airplanes, the engine instruments are still the most important instruments on the panel. There are some who will argue that point, but think about it for just a few minutes and you can't help but agree. If you lose your altimeter while in full IFR conditions, you get a dry mouth and wet hands. But lose your engine oil pressure just as suddenly under the same conditions and your concern could get considerably worse.

You could manage without an airspeed indicator—many of us have—but what would you do without a manifold pressure gauge on a turbocharged single? Not only do these gauges enable



you to keep engine operation within the prescribed operating limits, but often they can warn of trouble before it becomes an actual crisis.

Perhaps most important of all engine gauges is the oil pressure, so let's begin with this instrument. Oil is the life blood of your engine, and pressure makes it flow through the engine. If for any reason that pressure is lost, the engine will quickly suffer the consequences of lubrication and internal cooling failure. It would suffice if all you knew about this instrument was the range markings and you monitored the gauge for operation within the specified limits. However, knowing a little more about this instrument and the system that it monitors may someday save your engine or even your life.

Essentially, there are two types of oil pressure gauges. One is a "wet" type which means that a small hose is connected between the engine oil pressure system and the instrument on the panel in the cockpit. This line is filled with oil, and when the system builds up pressure that force will be reflected through the line directly to the gauge causing it to respond. The other type of gauge is electric. This system has a pressure transmitter installed in the engine's lubricating system, a type of variable resistor that will increase or decrease its electrical resistance according to the amount of oil pressure acting upon it.

The pressure gauge on the instrument is connected to the transmitter by wire. When the master switch is on, current flows through the gauge to the pressure transmitter and to ground completing the circuit. The gauge measures the amount of electrical pressure (volts) flowing through its circuit and its needle indicates accordingly, only the readings are in terms of oil pressure instead of volts.

Figure 1 illustrates each of the two systems. Each of the systems has its pros and cons and either can be found in present-day aircraft. Both systems are accurate and reliable when good equipment is employed. There are some minor differences in indication behavior and these, if applicable, will be explained along with indication data.

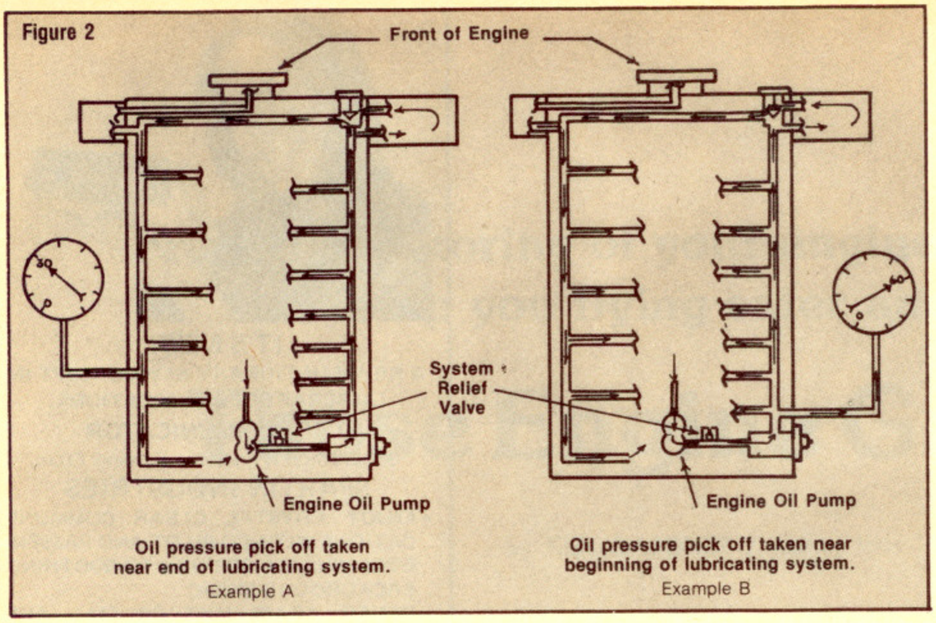
The primary purpose of the oil pressure gauge is to keep you informed of adequate engine oil pressure. Upon start-up in normal temperatures (40°F and above) you should have a pressure indication within 30 seconds (usually much sooner). In cold weather (below 40°F) this indication could take longer; however, 60 seconds is usually considered maximum.

If an indication does not occur within these limits the engine should be shut down immediately and the reason sought. The location on the engine where the oil pressure is "picked off" (source where taken) has a profound effect on how quickly you get a pressure indication after start-up and how high it will be at normal operating temperatures.

The engine's lubricating system consists of many passages through which adequate amounts of oil must flow to satisfy all lubrication and internal cooling needs. Flow through such a system is not without resistance, and the more complex the system the greater the resistance will be. Thus the pressure indications you see on the oil pressure gauge are actually a measure of resistance to flow.

Consequently, if you measure oil pressure immediately after discharge from the pump, you will see total system resistance or maximum pressure. If you measure oil pressure near the end of the system, you will see a much lower pressure indication because there is less system resistance. No doubt some may recall the law of physics that says pressure will act uniformly upon all areas of the vessel or system under pressure—but that law applies only to static conditions.

Under flow conditions pressure will be relative to resistance encountered. Therefore, as resistance decreases so will pressure. Pressure will also decrease with an increase in the temperature of the oil because the oil becomes less viscous, or freer flowing, as its temperature increases. With that refresher in phys-



ics, let's examine some typical lubricating system indications.

The illustrations in Figure 2 depict the two extremes possible in "picking off" system pressure. Example A has the pick-off point near the end of the lubricating system. At normal oil temperature the cruise oil pressure will be approximately 30 psi (pounds per square inch). The engine in Example B is the same engine only this time with the oil pressure taken very near its source.

With Example B we are seeing near-total system resistance, while in Example A we see only partial system resistance. Notice that a system relief valve is incorporated in the passage immediately after the outlet side of the pump. Under cold weather starting conditions (40°F or colder) the thick condition of single viscosity lubricating oils—especially SAE 40 and 50 (grade 80 and 100)—can cause the relief valve to open. This prevents hydraulic damage to the pump and system; however, it can also result in a considerable reduction in oil flow through the system.

With the relief valve open, the gauge in Example B will indicate substantial pressure because of its proximity to the source. The gauge in Example A would indicate little, if any, pressure under the same conditions. If your system was like Example A and you did not see sufficient pressure within the required 60 seconds, you most likely would shut down and investigate. With Example B you could be unaware of insufficient flow due to an adequate pressure indication on the cockpit gauge.

The gauge source in Example A will tend to indicate that the engine is slow to get up oil pressure during start-up while the other system would indicate almost immediate pressure. Actually, both engines develop oil pressure at the same rate. System A will only appear to take longer simply because of the distance the oil must travel prior to reaching the pick-off point. The advantage of this system is that you can be reasonably certain of engine lubrication when you do see a pressure rise on the gauge. While both pick-off points will provide an adequate oil pressure indication source, the one illustrated in Example A is capable of a more accurate assessment of system flow.

Merely providing an indication of adequate system oil pressure is not the extent of this instrument's ability. The oil pressure gauge can also warn of lubricating oil that is too cold for safe takeoff power. The pour point of SAE 30 (Grade 60) oil is 0°F. Below this temperature such an oil will behave more like jelly. On a –10°F morning you could start your engine and it might possibly develop an adequate pressure indication within the prescribed time limits.

At the low engine speeds of warmup and taxi some of the jellylike oil in the sump may succeed in flowing into the oil pump pick-up screen. Engine friction quickly heats it to liquid consistency whereupon it flows through the engine. But, on its return to the sump it flows over the top of the cold, thick oil still there and back to the pick-up screen. When the engine is revved for runup checks, there may not be a sufficient quantity of liquid oil to maintain pressure and the pump will cavitate (suck air). This condition will be reflected on the pressure gauge by needle fluctuations.

Those able to interpret such indications will throttle back and extend the warmup. It is possible to have enough liquid oil for runup but not for takeoff power demands. If the oil pressure gauge begins to fluctuate upon or after application of takeoff power it is more than likely that pump cavitation is being experienced due to insufficiently heated oil. Continued operation under such conditions could result in bearing damage or even complete engine seizure.

Excessive oil pressures (near or over top limits) during preflight runup or takeoff power nearly always are an indication of oil too thick for proper operation, whether it be cold weather or oil too heavy a grade to begin with.

Internal cooling is an important function of the lubricating oil, and the aircraft is equipped with an oil temperature gauge to advise you of internal cooling conditions. Oil temperature gauges are usually of two types: the direct-reading type or remote electric. The direct-reading type is connected by a metal tube to a probe that is inserted into the lubricating system at the desired source. Rising oil temperatures cause a fluid in the probe to expand and exert pressure through the same fluid in the tube to the gauge, which converts the expansion into temperature indications. Such a system is made as a complete unit and, if the tube is damaged enough to leak, the entire gauge unit must be replaced.

The electric type is quite similar to the electric oil pressure gauge described earlier. The temperature probe in this case undergoes a change in electric resistance when heated by the oil. The cockpit gauge translates such resistance changes into temperature indications.

If the engine has no oil cooler, the temperature probe is usually located in the low-pressure oil inlet screen to the pump. With this type of arrangement, indicated oil temperature will be that of the oil entering the pump. An engine equipped with one generally will have the probe located in or near the oil-cooler outlet port. Thus oil temperature indications will be relative to the source location and its subsequent circumstances and not necessarily the same throughout the engine. Oil temperature limits are influenced by the oil's limits rather than the engine's. Thus most oil temperature gauges are redlined at 225°F and are seldom marked below 75°F. The bottom peg is approximately 60°F.

During initial warmup a large portion of the oil in the supply sump could be considerably below the temperature that you see on the gauge because it is indicating the temperature of only the oil that is flowing over the probe. During normal operation at takeoff, climb, and cruise the temperature of oil contacting the hottest parts of the engine will be hundreds of degrees in excess of normal gauge indications. The indicated oil temperature is essentially a trend, or pattern, indication. Nevertheless, oil temperature indications can be useful beyond normal ranges.

Engines having no oil coolers will show a consistent differential between normal cruise temperatures for summer and winter. It is not uncommon for some to indicate near redline oil temperatures during hot weather climbouts. The same indications in cold weather warn of trouble. A sudden or rapid rise in oil temperature, especially in conjunction with any signs of engine roughness, is usually an indication of trouble. Such an indication could be caused by incipient detonation or preignition that has resulted from improper operating procedures. It could also indicate a burned piston to the point of leaking combustion gases into the crankcase. A slow but steady rise in oil temperature with no evidence of engine roughness could be indicative of loss of engine oil due to a leak that may have developed during flight.

An excessively low oil temperature coupled with higher-than-normal oil pressure during cruise in cold ambient temperatures usually indicates operation with oil too heavy for that particular engine or those ambient temperatures.

Engines with oil coolers add still other conditions that can be detected with the oil temperature gauge. Shortly after takeoff, especially in cold weather, the oil temperature gauge will rise in a normal manner to near its cold weather running indication, then suddenly drop an appreciable amount. This will be followed by several repeat performances, but with a lesser reduction each time before eventually holding a steady indication. Such a gauge behavior is quite normal and is indicating proper operation of the oil temperature thermostat which regulates the flow of oil through the oil cooler. Often the same situation will occur with power resumption after a long, power-off descent.

During climbout in extremely cold weather you might observe a steady rise in oil temperature with a gradual decrease in oil pressure. All other engine instruments remain normal; nevertheless, the situation continues with the oil temperature nearing the redline. What's happening? Most probably you are experiencing a congealed oil cooler.

When the oil reached its normal operating temperature, the thermostat directed oil flow through the cooler. The oil already in the cooler prior to start-up had cooled below its pour point and congealed. Once congealed it won't budge with normal system pressure. To preclude oil starvation the thermostat is designed to allow some oil to bypass the cooler. This, of course, results in rising temperatures which reduce viscosity, the thinner oil resulting in diminishing oil pressure.

If you continue operating with climb power, the oil temperature gauge can hit the redline and the oil pressure can fall to the minimum redline or perhaps even lower. What to do? Find an airport that has engine preheating equipment and use it.

Many newer airplanes have anticongealing radiators, but if yours doesn't you could experience a congealed cooler. While it is possible to have a gauge malfunction, this condition may often be verified by the indications from the other gauges. A rising oil temperature combined with falling oil pressure is not likely to be a gauge malfunction. Excessive insect clogging of the oil cooler can cause higher than normal warm weather oil temperatures.

The cylinder head temperature (CHT) gauge is equally valuable in monitoring engine operation. Earlier CHT gauges employed a spark-plug, gasket-type thermocouple connected to the cockpit gauge by means of wires. These wires have a calibrated resistance and must never be spliced or repaired. The later type instruments have a thermocouple looking somewhat like a miniature spark plug which is threaded into a special boss located on the bottom side of one cylinder head. The cylinder selected for monitoring CHT is arrived at by numerous flight tests by the aircraft manufacturer, not the engine manufacturer.

The thermocouple produces an electric current when acted upon by heat. The gauge measures this current and translates it into temperature indications. The cylinder heads heat and cool much faster than the oil does. As a result this instrument will appear to respond more rapidly. Engines certificated with the older, gasket-type thermocouple have maximum CHT readings around 530°F, while the maximum for the newer type is seldom above 460°F. This difference is due to the different sources of pick-off; consequently, one type of gauge must not be substituted for the other.

The CHT gauge can also warn of abnormal combustion situations since the cylinder head temperature is directly related to the combustion process. A sudden rise in CHT with no noticeable change in oil temperature or pressure could indicate a cooling problem. The cowl flaps may have slipped to a reduced position, or you may have flown into a much warmer air mass.

On a fuel injection engine such an indication could point to partial plugging of the injector nozzle on the cylinder having the CHT probe resulting in an excessively lean situation. If you suspect this, enrich the mixture and watch for a reduction in CHT.

Some types of exhaust heater muffs have internal baffles. Incidents have been reported where a loosened baffle has partially obstructed the exhaust port of the muff. This would cause an immediate rise in CHT, but would not appreciably affect oil temperature or pressure. Increasing cooling airflow or mixture richness would cause little, if any, change in the CHT. Detonation and preignition both will produce a fairly rapid rise in CHT, and an oil temperature rise will soon follow. Should you suspect either of these conditions, waste no time in reducing the power, enriching the mixture, and increasing cooling air flow. Both detonation and preignition are capable of causing extensive engine damage in the time it takes for an adequate rise in CHT.

A sudden complete drop in CHT indication in which the needle goes to full-scale cold usually indicates a broken wire between the gauge and the thermocouple. Erratic CHT readings are indicative of a loose connection in the gauge-to-thermocouple circuit. Poor contact or corrosion with the bayonet-type thermocouple on the underside of the cylinder head will result in lower than normal CHT indications along with sluggish temperature changes.

There are times when an abnormal CHT is actually normal under existing circumstances. For example, immediately after a TOH (top overhaul) or MOH (major overhaul) it is normal for the CHT to run approximately 75 to 100°F above normal at cruise. This should abate to normal within the first 25 hours of operation as the new parts wear in.

Tachometers are either mechanical or electric. The mechanical variety are driven by a flexible cable much like an automobile speedometer. The electric type has a small generator driven by the engine connected by wires to the cockpit instrument. Both indicate engine speeds in chankshaft rpm, except for some geared engines where camshaft speed is indicated rather than crankshaft. The latter is mainly a psychological approach to calm the fears some pilots have of the higher engine speeds of geared powerplants.

A mechanical tachometer can tell you when the drive cable needs lubrication. A noisy, fluctuating needle is nearly always indicative of this. A tachometer can also help check whether the engine's idle mixture is proper. With the engine at idle speed, quickly pull the mixture to full lean while observing the tachometer. If the needle hesitates or rises slightly (approximately 25 to 75 rpm), then falls off, the mixture is correct. A rise of more than 25 to 75 rpm indicates an over-rich idle mixture. An immediate drop of the needle spells too lean.

Perhaps the most important use of the tachometer is when it nears its red line or maximum rpm mark. Maximum rpm should not be exceeded, period. A 50-rpm overspeed may not sound like much, but it is when you consider that the forces resulting from centrifugal action on the engine's moving parts multiply as engine speed increases. The same is true for the propeller, which must also endure much greater forces during engine overspeed.

Last but by no means least is the manifold pressure gauge. Its primary function is to help you arrive at desired and proper power settings. But it can warn you of approaching dangers such as carburetor ice. Let's say you are cruising at 2,300 rpm with 23 inches manifold pressure and the ambient conditions are ripe for possible carburetor ice. After awhile you notice that the manifold pressure is down to 22 inches. If you find that IAS (indicated airspeed) is also less you can be reasonably certain of ice building up in the carburetor.

The manifold pressure gauge can warn when an overhaul is needed. If you once indicated 160 mph at 7,000 feet with 2,300 rpm and 22 inches manifold pressure and now you can only manage 150 for the same power readings, your engine is not as efficient as it once was. Another example is manifold pressure at normal idle speed. The lowest possible manifold pressure an engine can run at occurs only at idle speed—the lower the idle manifold pressure the more efficient the engine is. As the engine draws near to a needed overhaul the idle manifold pressure will be greater than when it was in good mechanical health.

These five basic engine gauges are a key to the longevity of your aircraft's powerplant. Properly interpreted and respected, they can benefit not only your flying, but your pocketbook, as well. □