

TIPS ON ENGINE CARE

 **Teledyne Continental Motors**
Aircraft Products Division

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FOREWARD

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AOPA PILOT MAGAZINE

NATIONAL PILOTS ASSOCIATION

SPORT FLYING MAGAZINE

AIRPORT SERVICES MAGAZINE

FLYING MAGAZINE

THE AIRCRAFT POWER REPORTER

DON'T BABY YOUR ENGINE

“Reprinted from AOPA Pilot Magazine”

Some pilots do and the results are often quite discouraging. “Engine babyers” mean well by their engines, in fact they have been lead to believe that by not using all of the available power for take-off and cruising with low power settings, they are conserving their engine. Usually this type of thinking is the result of experience with the stock automobile engine. In reality the aircraft engine has very little in common with the stock automobile engine in terms of operating procedures. The aircraft engine is the athlete of its species and it was designed for high power output. If this be the case, then you are not going to do it any disservice by using full power for take-off and 65 to 75% power for cruise. Even in view of these statements, many pilots are still reluctant to fly their engines at high power settings simply because they are still not convinced that such operation won't hurt the engine. If you are one of those pilots “not quite convinced” perhaps it would help if you knew what your engine had to do to prove itself before the FAA would grant a type certificate for its production.

Let's say that you are flying an airplane powered by a Teledyne Continental Motors Model O-470-R engine. This engine, like any other, began on the drawing boards. From the drawing boards it became actual hardware and then it entered the developmental stage. Now a period of considerable testing and refinement follows until an engine ready for production finally emerges. However, before actual production and subsequent sale of this engine can begin, it must pass an FAA type test. The first type test engine and here is what a type test involves.

The type test engine is mounted in a cell and given a standard production acceptance test. After completion of this series of runs, the engine is ready to begin its type test (also called an endurance run). The engine will now be operated at full power (maximum rated manifold pressure and maximum rated RPM) for a period of 50 hours. During this period, the engine's CHT and OT (cylinder head temperature and oil temperature) will be held at normal range (first 2/3 of the green arc on your airplane gauges).

Upon completion of the first 50 hours, the engine is checked and made ready for the second 50-hour period. During the next 50 hours, the engine will continue at full power—only this 50 hours will be at red line CHT and OT. Imagine that! – fifty hours at “full bore” with red line temperatures.

The last 50-hour phase will be alternating sequences of 65 to 75% power and at red line CHT and OT. Often I am asked how we are able to control temperature with the engine running, especially at full power. Cooling shrouds are placed over the engine in the test cell and actual cooling air is supplied from an outside blower. The minimum number of

hours required by your FAA is 150 and in the sequence just described. Engine manufacturers often exceed this figure by as much as two or three times simply for their own satisfaction that all is well and the engine is trouble free.

After all type test running is completed, the engine is removed from the test stand, completely disassembled and every part carefully examined. Each moving part is checked with measuring instruments to determine if any appreciable wear has taken place. Each part must be able to pass the blueprint specifications for new parts. Now let's sum all of this testing up in terms of pilot or owner benefits.

The type test engine operated for 100 hours at full power, 50 hours of this time at red line temperature and still another 50 hours at red line temperature during the 65 to 75% power run. A minimum of 150 hours total, often more and during all of that demanding operation, no parts failed and during all of that demanding operation, no parts failed and actual wear of moving parts was for all practical purposes, negligible. You would have to fly your engine six minutes every hour at full power and for 1000 hours just to equal that portion of the test. A type test is quite an achievement in the eyes of most pilots but isn't to the engine manufacturer. The type test is simply proof that the engine is able to do the job for which it was designed, and that the materials from which it is constructed are equally capable.

Now let's talk about all the other production engines that will follow the type test engine. Each new production engine is given a standard production acceptance test. The last part of this test is the oil consumption run and is conducted at full throttle. The purpose of this test is initial seating of the piston rings to the cylinder walls. The run is conducted at full power because that is where greatest B.M.E.P. (Brake Mean Effective Pressure) occurs and a high B.M.E.P. is necessary for good piston ring break-in. The test house at the factory determines initial piston ring seating by the amount of oil consumed by the engine during this run. Only a few hours are involved in the acceptance test and the new engine is by no means completely “broken in”. The finishing up break-in rests with the pilot who will be flying the engine during the first 100 hours of its life.

The cylinder walls of a new engine are not mirror smooth as one might imagine. A special hone is used to put a diamond like pattern of “scratches” over the entire area of the cylinder wall. Figure 1 shows a magnified view of these “scratches” (technically defined as cross hatch). The cross hatch treatment of the cylinder walls plays an important role in proper break-in of piston rings to cylinder walls. Earlier I mentioned that B.M.E.P. was necessary to the “break-in” process. Here is how it works.

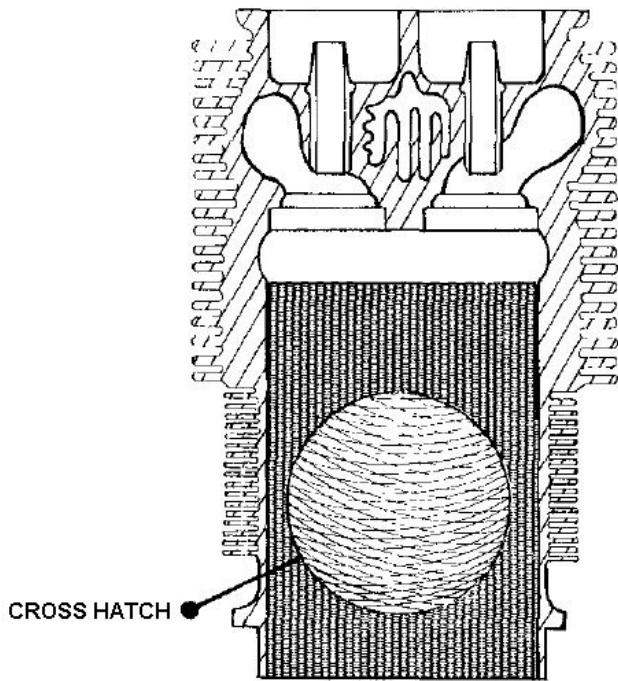


Figure 1. Above is a highly magnified view of the cross hatch pattern honed into the cylinder's surface.

Figure 2 illustrates a cutaway of piston, ring and cylinder wall as these components would actually appear during normal operation in a new engine of very little time.

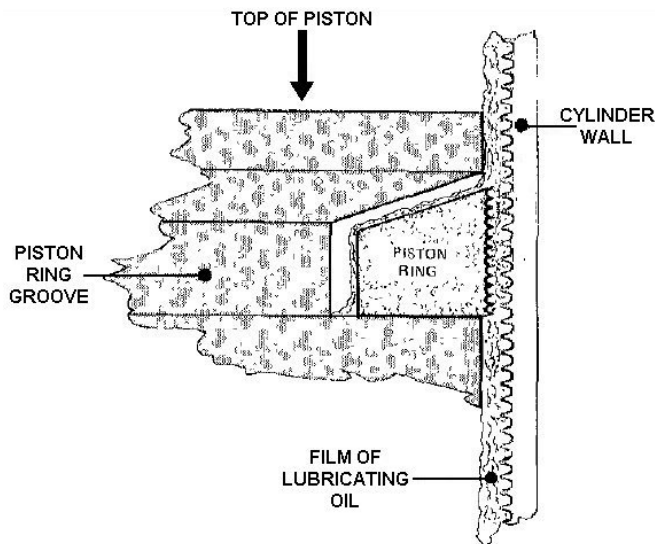


Figure 2. Notice the "saw teeth" like surface of the cylinder wall and piston ring face. In this illustration the piston ring is being held away from the cylinder wall by a film of lubricating oil. This drawing is considerably exaggerated in the interest of better understanding.

The illustration is considerably exaggerated for effect, in reality the "saw teeth" effect would not be that pronounced. Notice that a film of lubricating oil holds the piston ring away from the cylinder wall. Proper break-in of piston ring to cylinder wall requires that the ring rupture or break through this oil film and make contact with the cylinder wall. During

such "metal-to-metal" contact, the little peaks on the ring face and cylinder wall become white hot and rub off. This condition will continue to occur until the ring face and cylinder wall have established a smooth compatible surface between each other. At this point, break-in is said to be relatively complete and very little metal-to-metal contact will occur hereafter. In fact, as the break-in process progresses, the degree of metal-to-metal contact will regress.

There is one little "sticky wicky" in this process, that film of lubricating oil is there to *prevent* metal-to-metal contact. That's exactly what it will do and really that's what we want it to do. However, during the break-in process, we must have some minute metal-to-metal contact as previously explained. Therefore, rupture of the oil film is necessary. Two factors under the pilot's control can retard this necessary rupture...low power and improper lubricating oils during the break-in period. Engine lubricating oils can be divided into two basic categories, compounded (detergent and ashless dispersant) and non-compounded. The compounded oils are superior lubricants with a greater film strength than non-compounded oils. Consequently, only non-compounded oils should be used during the break-in period. Some owners insist on using additives or super lubricants along with the regular engine oil during the break-in period. They believe that such practice will aid the engine during its breaking in. With all due respect to such good intentions, this practice is wrong and actually causes harm.

Figure 3 is an exaggerated illustration of oil film rupture during the normal break-in process. Note that the points or ridges of the honed-in scratches have partially worn away. During the actual oil film rupture, only the ridges on the piston rings and cylinder walls contact each other. The little "valleys" between the ridges retain a film of oil and thereby prevent a total dry condition between piston ring and cylinder wall. Notice in Figure 3 how B.M.E.P. or combustion pressure forces the ring against the cylinder wall. This is the "key" to the break-in process. You can see then that low power (low B.M.E.P.) won't provide the same results and the break-in process will require a longer period of time. However, time in this instance will have a detrimental affect on your engine because any prolonged, low power break-in procedure usually leads to "glazed" cylinder walls.

During each power stroke, the cylinder walls are subjected to very high temperatures, often 4000 degrees F. or higher. This period is very brief but nevertheless, long enough to cause oxidation of minute quantities of some of the lubricating oil on the cylinder walls. Some of this oxidation will settle into the "valleys" of the honed cylinder wall "scratches". Eventually this situation will fill the "valleys" of the cylinder walls creating a smooth, flat surface. This is also a normal situation; however the ring break-in process practically ceases when these valleys become filled or "glazed" over. If this "glazed" over process occurs before break-in is complete, in modern day language, "you have had it". Excessive oil consumption resulting from incomplete ring seating will present itself and the only certain remedy is re honing the cylinder walls. This is both expensive and unnecessary.

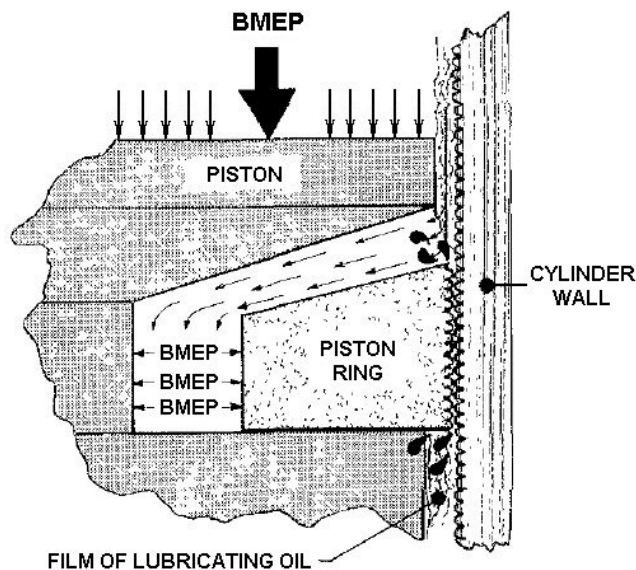


Figure 3. This is an exaggerated illustration of oil film rupture and subsequent ring to cylinder wall contact. Notice the BMEP arrows pushing the ring down on its ring land and pushing between ring groove wall and the back of the piston ring. This is how oil film rupture occurs. Notice how the "point" of the honing scratches have become flat on top. This is how the mating of piston ring to cylinder wall occurs.

Well now you know the whole story, so let's examine the few simple steps necessary for proper break-in of any new, remanufactured, major or top overhauled engine.

Pick a good quality, non-compounded aircraft engine lubricating oil and stay with it throughout the break-in period. Duration of the break-in period is usually defined as the first 50 hours or until oil consumption stabilizes.

Do drain and replace engine oil as often as recommended by your owner's manual. If operating conditions are unusually dusty or dirty, more frequent draining may be

necessary. Remember, no one ever wore out an engine by changing oil too often. Oil changes are more critical during the break-in period than at any other time in the engine's life.

Do use full rated power and RPM for every take-off and maintain these settings until at least 400 feet of altitude above the departing runway is attained. At this point, reduce power to 75% and continue the climb to your cruising altitude.

Do maintain 65 to 75% power for all cruise operation during the break-in period. Avoid high altitude operation with non-supercharged engines during the break-in period. Altitudes in excess of 8000 feet density will not permit sufficient cruise power development with non-supercharged engines. Interrupt cruise power every 30 minutes or so with a smooth advance to full available manifold pressure and RPM for 30 seconds then return to original cruise settings (non-supercharged engines only). This procedure helps to hasten a good break-in. The procedures suggested in this paragraph apply primarily to the break-in period and are not necessary thereafter.

Avoid long power-off let downs especially during break-in period. Carry enough power during let down to keep cylinder head temperatures at least in the bottom of the green.

Keep ground running time to absolute minimums especially during warm weather. During the break-in period, it will be better to delay departure than to sit at the end of the runway for 15 minutes or more running in high ambient temperatures.

Be especially generous with mixture controls and cooling air during break-in. All take-offs should be with a full rich mixture except from altitudes in excess of 5000 feet and then take care to lean only enough to restore power lost from overly rich mixtures. Make your climbs just a little flatter in hot weather to assure adequate cooling air.

Follow these simple recommendations during break-in and your engine will reward you with a healthy service life. And above all "Don't Baby Your Engine During Its Break-In Period".

HOT STARTS

"Contributed by the National Pilots Association"

"Hot Starts" Remember that phrase? It used to be quite common and to most mechanics and pilots it was, or perhaps still is, synonymous with the gas turbine engine. In recent years it has spilled over into some of the reciprocating power plants which power the general aviation fleet. However, the meaning is quite different when applied to modern reciprocating and implies difficulty in starting the power plant when it is hot or heat soaked from recent use.

This condition is primarily associated with fuel injection engines and usually occurs only during hot summer weather. This situation is further aggravated by the fact that the pilot-

owner of today does not know as much about his airplane and engine as his predecessor once did. There are many valid reasons why he is not as knowledgeable, but the fact remains, and this new bred of pilot-owner and the machines he flies are steadily increasing in number with each new day. So let's get acquainted with "hot starts" as applied to fuel injection engines.

Maybe you already own an aircraft powered with a fuel injected engine and if so, you are aware of the simplicity of its starting procedures. As a matter of fact, there isn't much difference in starting procedures between fuel injection and

carburetor engines and both are quite simple under all normal conditions – although there are times during hot summer temperatures and under certain conditions when a fuel injected engine may not start as easily as its carburetor-fed cousins. While this is no major difficulty, it can be annoying.

There is a sound reason for this little annoyance and once you understand what provokes it and how your airplane is equipped to handle it, you'll know exactly how to avoid it.

The engine in a modern airplane is closely cowled to reduce airframe drag and subsequently increase the overall efficiency. Consequently, there is very little space inside the cowling and it is void of any unnecessary openings. Figure 1 is typical of such an installation.

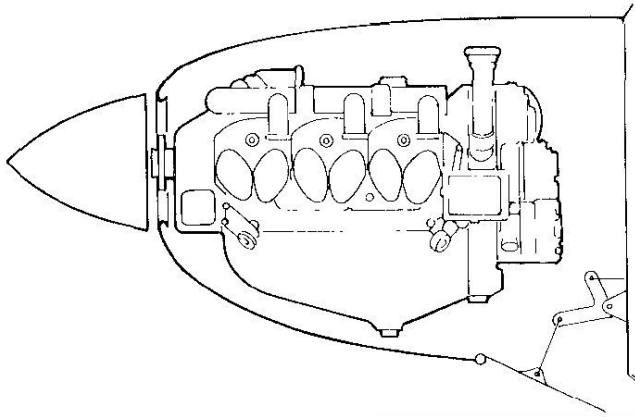


Figure 1. Typical example of a tightly cowled engine in a well designed airframe.

Close Cowling Traps Heat

Cooling of the engine depends on air being forced into the cowling by the propeller during operation and the “ram” effect during flight. Figure 2 illustrates airflow during inflight conditions on a typical installation. Of course when the airplane is on the ground and the engine is at rest, no cooling is necessary. But! – things do get a bit warm inside the cowling immediately after shut-down. This temperature

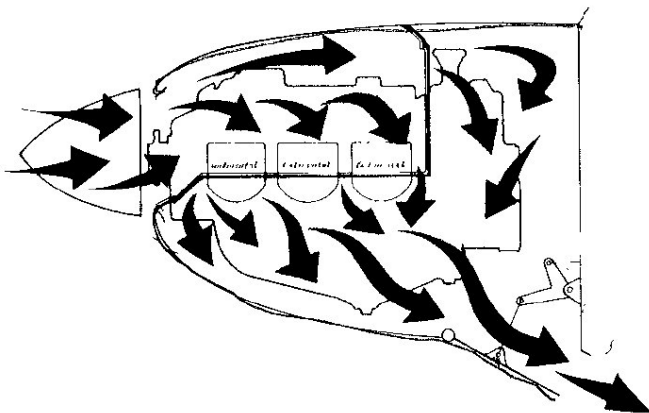


Figure 2. Notice how air entering the cowling opening in the front is forced around the cylinders by means of baffles and moves into the lower cowling where it passes overboard through the cowl flap openings. Cooling air also enters the accessory section via strategically located vents.

rise results from the fact that the air trapped inside the cowling is heated by residual engine heat.

This condition can occur in nearly all modern airplanes, twins and single engine alike, and especially so on those airplanes having no upper cowl openings. On a hot summer day it will take approximately two or three hours for this trapped heat to dissipate appreciably. And here's where “hot starts” get started.

What actually happens? Within ten to fifteen minutes after shutdown in hot weather, the heated air inside the cowling heats the fuel in all of the lines and fuel metering components located inside the cowling and forward of the firewall.

Under these conditions the liquid fuel begins to expand and vaporize. If the fuel selector valve is left on (and normally it should be) the pressure from the expanding fuel begins pushing the liquid fuel remaining in the lines back to the fuel tank from which it came. Figure 3 illustrates this condition.

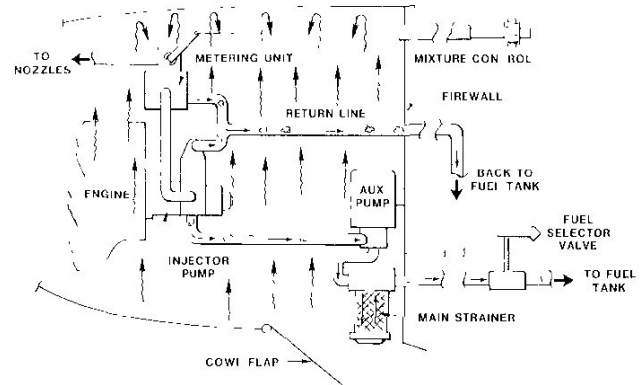


Figure 3. A simplified, though typical diagram of the fuel supply system and its components forward of the firewall. Notice how the heated air rises to the top of the cowling. All fuel lines are shown in X-ray fashion to show what happens inside. Notice the puffs of vapor separating the liquid fuel and that expansion has begun to force the fuel back to the full tank.

Very quickly most of the fuel in the lines and components inside the cowling will have turned into vapor. If the fuel selector valve was turned *off* after engine shutdown, the expanding vapors then force the liquid fuel and vapors through the fuel metering equipment and into the engine's induction manifold, eventually to escape into the atmosphere.

Since we prefer to keep the fuel for turning the propeller rather than permeating the atmosphere, it's better to leave the fuel selector on – this way the vaporizing fuel pushes its way back to the tank from which it came.

PUMPS AND METERS – HOW THEY WORK

All airplanes equipped with fuel injection have at least two fuel pumps, one engine-driven injector pump and one electric “auxiliary” or “booster” pump. The injector pump can deliver fuel only when the engine is running or being cranked. The electric auxiliary fuel pump can be operated anytime, whether the engine is running or not.

As its name implies, the auxpump serves a variety of purposes, including the complete elimination of “hot start” situations.

The engine-driven injector pump differs considerably from the pump used for carbureted engines. On carburetor type engines the fuel pump usually serves one basic purpose: supplying fuel to the carburetor from the storage tanks in the airplane. On an injection system the engine-driven pump provides several functions. In addition to supplying fuel, the injector pump also contains some of the metering equipment and therefore provides some of the initial metering.

All engine-driven fuel pumps must have the capacity to provide more fuel than the engine can use, even at full throttle. The automotive (diaphragm) type pump simply recirculates this excess delivery within its chambers. Since the injector pump operates at higher pressures and delivery, it is provided with a return line system. The injector pump also supplies more fuel to the metering equipment than is needed. This excess fuel returns through the return system to the tank from which it came (see Figure 4).

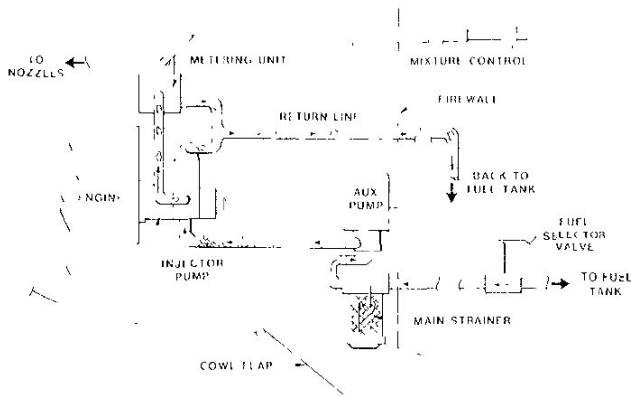


Figure 4. This illustration shows normal fuel flow when the engine is running. Note the return of excess fuel from the injector pump and metering unit. This excess fuel returns to the tank from which it came.

All injector pumps are fitted with a bypass valve which allows the auxiliary pump to bypass the vane portion of the pump and yet utilize the metering section of the injector pump when the injector pump is inoperative. During normal operation the injector pump draws fuel from the tanks, meters it to some degree, to the metering unit or control.

The metering unit contains the fuel metering valve, which is mechanically linked to the air throttle. On some engines the metering unit also contains the mixture control, while other installations have the mixture control built into the injector pump. In either case, fuel passes through the mixture control valve prior to reaching the fuel control metering valve.

Whenever the pilot moves the throttle, the fuel metering control will move in direct or related proportion. The metering unit is also provided with a return line for returning excess fuel which isn't delivered to the cylinders for combustion. The return line from the metering control connects to the return line on the injector pump and from here the return system goes back to the storage tanks or (in some installations) to a small hopper tank located somewhere along the main fuel line. This return system

plays a very important role in preventing “hot start” difficulties.

The Auxiliary Pump

When you turn on the auxiliary pump, it draws fuel from the storage tank and delivers this fuel under pressure to the engine driven injector pump. If the engine is at rest, fuel from the auxiliary pump will pass through the injector pump bypass valve and into the metering section of the injector pump. The partially metered fuel leaves the injector pump and flows on to the metering control.

If the mixture control is open, the fuel arriving from the injector pump will continue on to the distributor valve and nozzles. However, if the mixture control is placed in cut-off or full lean position, the fuel leaving the injector pump will arrive at the mixture control in the metering unit and then enter the return line system. Once in the return line system, the fuel returns to the tank from which it came.

To “Fix” a Hot Engine

Ready? Let's start a typical fuel-injected engine that's been shutdown for approximately twenty minutes when the ambient temperature on the ramp is 90°F.

Procedures for a routine, warm engine start on this fuel injection engine would consist of:

1. Mixture control – Full Rich,
2. Throttle – “Cracked” or slightly open,
3. Magneto switches – On (if separate from starter switch)
4. Starter – Engage.

Usually a small amount of liquid fuel will remain in the injection lines leading to the nozzles. As the engine begins cranking, this retaining fuel is injected into the intake valve ports (Figure 5) and drawn into the cylinders. Upon ignition,

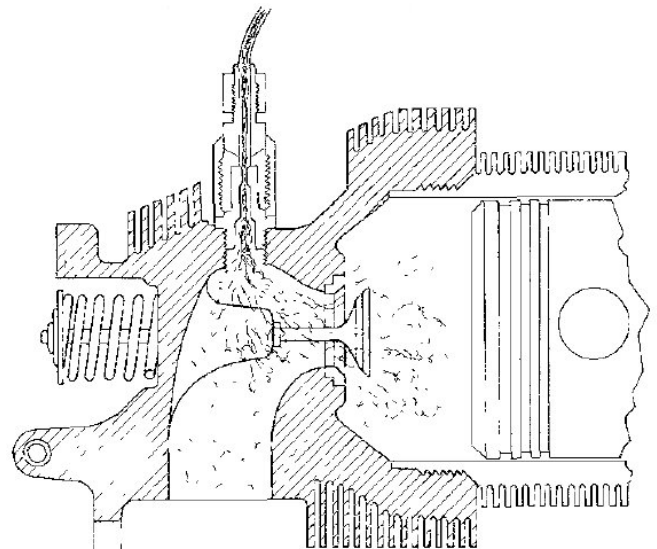


Figure 5. Fuel enters the intake valve port by way of the injector nozzle located in the cylinder head, and then passes into the cylinder through the open intake valve in the usual manner.

the fuel ignites and the engine bursts into life; then, just as suddenly as it started, it dies. A false start and the prima facie indication that a “hot start” situation exists.

Since the fuel lines inside the cowling are full of vapor rather than liquid fuel, the engine driven pump will not pump or “move” the vaporized fuel in sufficient quantity to support combustion. Therefore, the engine’s refusal to continue running after the initial start up is simply due to fuel starvation.

“Words” Won’t Help

Such false starts will usually be followed by difficulty in re-starting. The unknowing pilot will continue cranking the engine while resorting to some favorite procedure, self-designed, to accommodate the situation. If this doesn’t bring forth immediate results, more cranking and different procedures are tried, sometimes accompanied with “words” expressed in a manner designed to encourage the engine to be *more cooperative*. At last (usually) the engine starts but only because the excessive cranking has pumped away the vapor, permitting liquid fuel to fill the lines and returning things to normal.

There has to be a better way – and here it is, in three easy steps:

1. Mixture control – Full Lean or Cut-off.
2. Throttle – Full open
3. Electric auxiliary fuel pump – On high.

Relax for approximately twenty seconds and while you are waiting, here is how the solution is working for you.

The electric fuel pump is taking liquid fuel from the tank selected and pumping it through the heat-soaked lines under the cowling. In its cut-off position, the mixture control prevents this fuel from reaching the cylinders. This is exactly what is needed at this moment: Now the fuel takes the alternate path and returns to the tank or header from which it came.

Fuel Flow Purges Lines

During this process, the continual flow of fuel will purge the lines forward of the firewall of all vapors. Also this continued flow will reduce the wall temperature of the lines through which it passes. After approximately twenty seconds the fuel lines will have cooled sufficiently to retain the fuel in a liquid state after the pump is turned off. Figure 6 illustrates the purging process.

After twenty seconds, turn off the electric pump and make a normal start as follows:

1. Mixture control – Full rich.
2. Throttle – Cracked or partially open.
3. Starter – Engage.

No priming will be necessary because a small amount of fuel will make its way past the closed mixture control and into the nozzles during the purging operations. If this “three step” purging operation is conducted exactly as outlined, the engine will respond to a normal warm start procedure every time, and with no difficulty.

Just remember:

1. The *mixture control must be full lean* – to prevent flooding and to force the circulating fuel to flow back through the return system.
2. The *throttle must be full open* – because some single engine fuel injected aircraft incorporate switches in their throttle linkage to prevent the auxiliary pump from operating in the high position when the throttle is retarded.
3. The *auxiliary pump must operate in the high position for approximately twenty seconds* – to provide sufficient time to adequately cool the fuel lines and components inside the cowling.

Three to Remember

Finally, let’s summarize the three important facts that you should remember about “hot start” difficulties:

1. The cause of this possible difficulty is simply heat soaking of the fuel lines inside the engine cowling or nacelle after engine shutdown in hot weather.
2. The actual condition is temporary fuel starvation due to vaporization of fuel in the lines inside the engine cowling.
3. The solution for preventing the difficulty is the auxiliary fuel pump which simply purges the vapors and hot fuel from the lines prior to starting.

It’s just that simple.

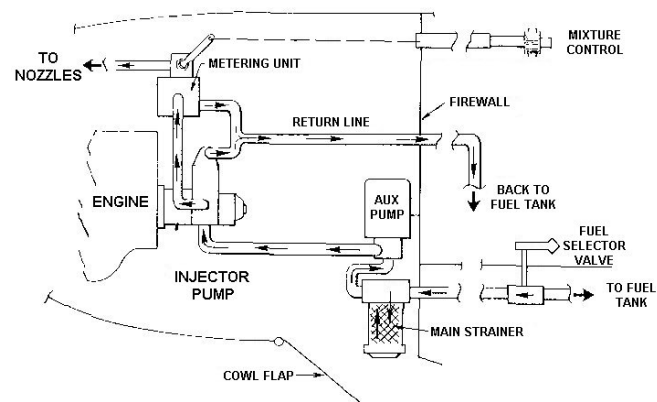


Figure 6. The electric pump is operating and you can begin to see the results. The supply line from the electric pump to the injector pump is almost free of vapors. Notice the vapors being returned through the return line system and that no fuel is passing the mixture control to the nozzles.

GROUND RUN-UP

“Reprinted from Aviation Mechanics Bulletin”

The reciprocating, air cooled aviation engine is not new to many of us. In fact it's been with us even prior to World War I and that's a long time anyway you choose to measure it. But the air cooled engine of today is considerably different from its predecessors. One of the important differences is the cooling requirements of the modern air cooled engines.

The early engines were velocity cooled. Figure 1 is a typical example of this type of cooling. These engines had little if any baffling and cooling was entirely dependent on the velocity of air flowing over the cylinders. Cooling on the ground was accomplished by the propeller and in flight, forward motion provided the necessary air flow.

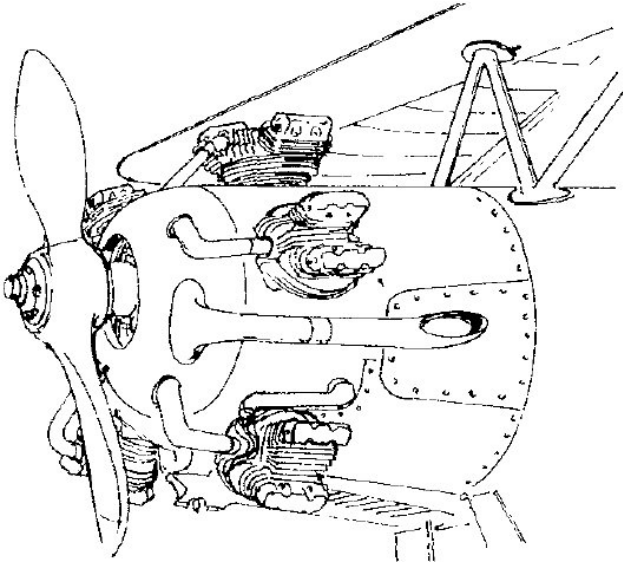


Figure 1. Velocity cooling.

Velocity cooling left something to be desired in that it did not provide uniform air flow around the entire cylinder assembly. This deficiency is illustrated in Figure 2. Notice the turbulence and lack of air flow contact on the rear side of

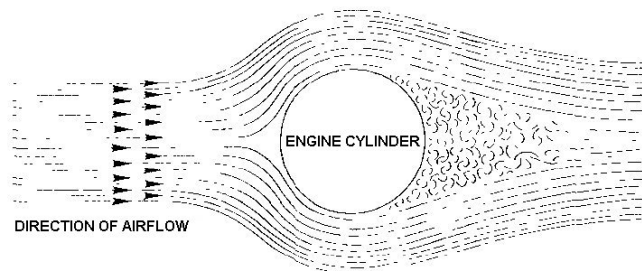


Figure 2. Airflow pattern around engine cylinder with velocity cooling.

the cylinder. This is typical of velocity cooling. However this type of cooling was satisfactory for these early engines. The compression ratios were often little more than 5 to 1 and the maximum “revs” were seldom more than 2000. Consequently, the amount of excess heat dissipated from the cylinder barrels and heads could be safely removed by velocity cooling.

As the fledgling aircraft industry grew, so did the performance demands placed on the engine manufacturers. These demands are chiefly: more horsepower, higher efficiency and greater reliability. However these demands cannot always be met by simply increasing the size of the engines.

So the compression ratios went up, but so did the amount of dissipated heat that had to be removed from the engine. The RPM's increased and this too brought increased cooling requirements. The point was reached where aircraft engines could no longer be adequately cooled by the velocity method. Cowlings were placed around the engines and baffles were installed between the cylinders. Now the cooling air could be directed around the entire area of the cylinder. Thus pressure cooling was born and the results were superior as well as uniform engine cooling. Figure 3 illustrates an early pressure cooled, static radial engine.

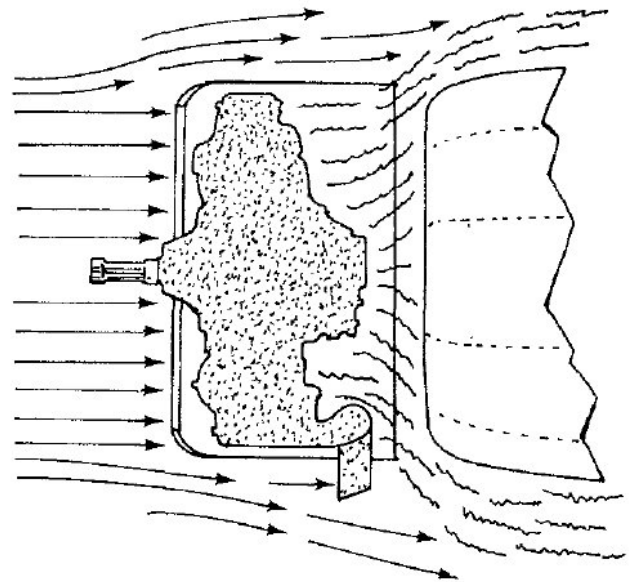


Figure 3. Early form of pressure cooling incorporating a NACA cowling.

Most of the early 4 cylinder, horizontally opposed engines were velocity cooled like their radial cousins. However as these engines increased in size, they too had to be pressure cooled. As the aircraft industry grew, the state of the art

improved and engine cowlings became streamlined as illustrated in Figure 4. Consequently the space inside the cowling decreased. The proper cooling of engines in such aircraft now became an exacting science.

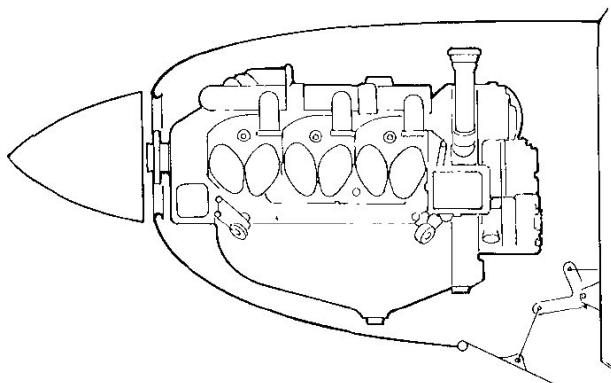


Figure 4. Typical streamlined installation of a pressure cooled power plant.

The baffling installed on the engines of today is the result of considerable study. Special wrap around baffles now guide the cooling air completely around the cylinder heads and barrels. Other baffles channel cooling air into oil radiators and cooling ducts for various accessories. Rubber seals are provided along the cowling edges of the baffling. These seals are very important since they provide the necessary air tight seal between the baffling and the cowling. Therefore every baffle and its seal must be in its proper position and in good working condition, or satisfactory cooling will not result.

Figure 5 illustrates a typical air flow pattern around a modern engine installation. Notice how the cooling air “piles

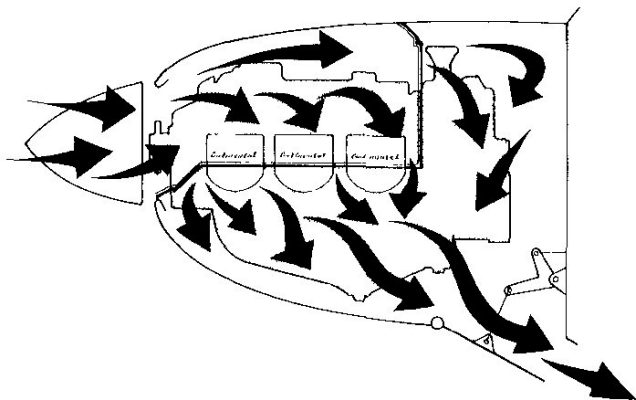


Figure 5. Cooling airflow pattern around a typical modern engine installation.

up” inside the cowling and then is channeled around the cylinders. Cooling air is also entering the accessory section to provide the necessary cooling for engine driven accessories. The air in the top side of the cowling is actually under pressure and it is this pressure that forces it to take the desired routes provided by the baffling. One doesn’t have to be an engineer to realize that in such an installation, cooling air simply wouldn’t take the desired routes if it were not for this pressure we keep emphasizing.

Where does this pressure come from? Well there are two sources we depend on and you already know what they are; ram air from forward movement or flight, and the propeller during ground operation. Since our subject is primarily ground run up, let’s examine the propeller’s capability in providing this pressure.

One look at the cooling air inlet openings on a modern airplane will quickly convince you that they are small by comparison to earlier installations. Figure 6 illustrates a typical installation. Now look at the shape of the propeller blade where it passes the cooling air opening in the cowling as illustrated in Figure 6. Not much airfoil section present in

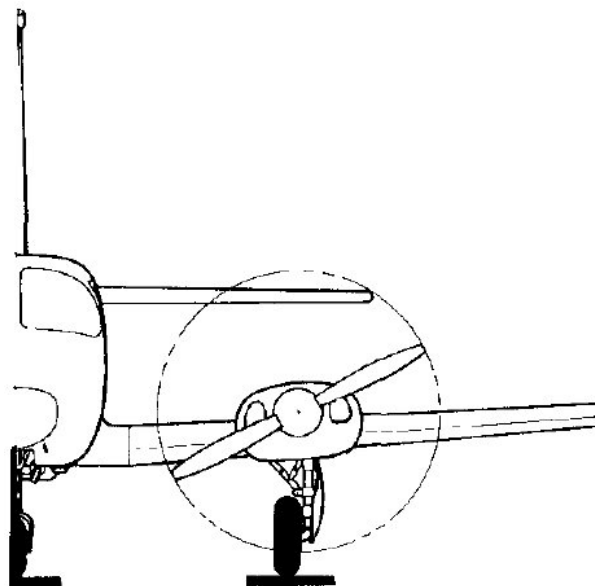


Figure 6. Cooling air openings in a typical well designed installation.

this area of the propeller is there? The airfoil section of the propeller usually starts about halfway across this cooling air inlet opening in the cowling. However the design is good and if plain common sense is exercised in ground run up, adequately pressure for cooling will be supplied by the propeller.

The rules of ground run up are the same today as they were for velocity cooled engines and they are now more important than ever. Yet it is not uncommon to walk across an airport ramp and see these rules profaned by both pilots and mechanics. Why does this happen? Well perhaps because we get a little careless in our daily routine or maybe because it doesn’t appear to cause any harm to the engine. The latter of these two excuses is probably the most commonly accepted and it is also the biggest progenitor of future troubles.

Excessive ground run-up, especially in the area of high power can cause damage to pressure cooled engines. The worst thing about such abuse is that it produces an accumulative type of damage. The damage is seldom great enough to show up right at that moment of abuse. Instead it goes by undetected, but it accumulates with more abuse and finally it shows up “way down the road” in the form of broken piston rings, scored pistons or cylinders or perhaps a

premature overhaul. This delay in development is the worst part of this situation. Because of it the pilot and or mechanic seldom connect the results with the cause. Consequently the shop manager is “hard put” to explain to the owner how this could have happened. In the end it is the engine’s reputation that usually suffers and for something that shouldn’t have happened. So let’s review those rules of ground run-up:

1. Always face the engine into the wind when running up, it helps.
2. Avoid prolonged or unnecessary run-up.
3. Avoid high power run-up except when absolutely necessary for maintenance checks and then only as long as necessary.
4. When high power run-ups are necessary, be certain you idle the engine at 600 to 800 RPM for a few minutes prior to shutdown. This will remove the excess heat developed during the high power running.
5. Some of the modern turbo-charged engines are ground boosted as well. Such an engine will quickly overheat from excessive, high power run-up. Remember this when you run these engines at high power on the ground.
6. Remember that the turbo-charger is also located inside the cowling. The turbine gets “red hot” during normal high power operation. This heat is constantly dissipated overboard in flight, but it’s a different story on the ground. So allow ample cooling down at fast idle (600 to 800 RPM) prior to shutdown.
7. Don’t run-up without the induction air filter or with carburetor heat on. Both of these abuses permit dirt to enter the engine.
8. Don’t run the engine up with the propeller in steep pitch except for the momentary propeller pitch check.
9. Don’t start or attempt to run-up an engine on the ground with the propeller feathered. If the propeller is not equipped with an auxiliary unfeathering system, use blade beams to unfeather it prior to start up.
10. Always open all cowl flaps and cooling devices during run-up, even during cold weather.
11. *Never* but *never* attempt to “burn out” a magneto drop his “time honored” procedure succeeds only at the expense of the engine’s mechanical health.
12. Don’t ever run an engine up under high power with the cowling removed.

Rule number 12 is one of the most important and yet most often profaned. Running the engine at idle speed while making an idle mixture adjustment is not so bad. This only takes a minute or two at the most and the engine isn’t developing any appreciable amount of power. Under these circumstances the amount of dissipated heat is not so great. The only trouble is that it doesn’t stop here.

Figure 5 illustrates proper air flow around the engine’s cylinders and as stated earlier this is possible only when the upper cowling is pressurized. Now look at the same illustration in Figure 7 only with the cowling removed. Notice that air is flowing over and around the engine but not around the cylinders where it is needed most. While this is an illustration, it is no exaggeration. Running a pressure cooled engine without its cowling simply will not provide adequate cooling. What do you suppose happens to those

round cylinders under such distorted cooling conditions? Distortion is correct and imagine what conditions that imposes on the moving parts inside those cylinders.

You are also correct when you say that a considerable amount of time and effort would have to be expended in removing and replacing the cowling during routine maintenance run-up procedures. However this is *not* justification for improper operation and the subsequent damage it could cause. There is a simple and easy solution.

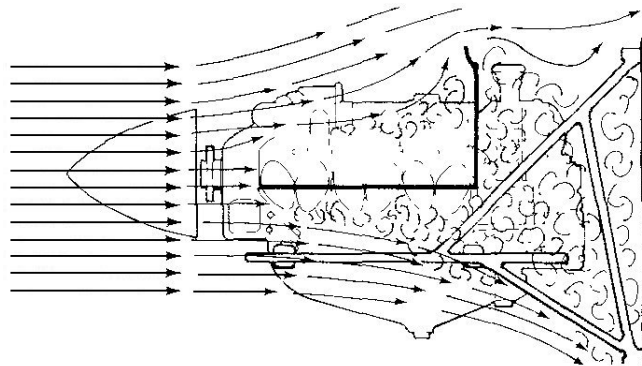


Figure 7. Airflow pattern over uncowled pressure cooled engine.

Any A & P mechanic can easily construct a simple sheet metal scoop similar to the type we use in the test house. Such a scoop can be quickly installed or removed. Those designed in the field are usually held in place with powerful bungee cords. Installation of a cooling air scoop provides the necessary volume of air and subsequent pressure to give adequate cooling. In most cases, the cooling scoop will not even interfere with the maintenance adjustments. Consequently, it can be left in place until you have completed your run-up requirements. Figure 8 illustrates a typical cooling air scoop installation. Notice that cooling air is flowing around the cylinders to provide adequate cooling and yet the accessory section is completely open.

Well now that you have had a chance to think about it, why not build a cooling air scoop? It won’t cost much and it won’t take a great deal of time either. The reciprocating aircraft engine of today is truly the athlete of the species. It’s efficiency and reliability exceed any other period in its history. But remember it is not immune to abuse.

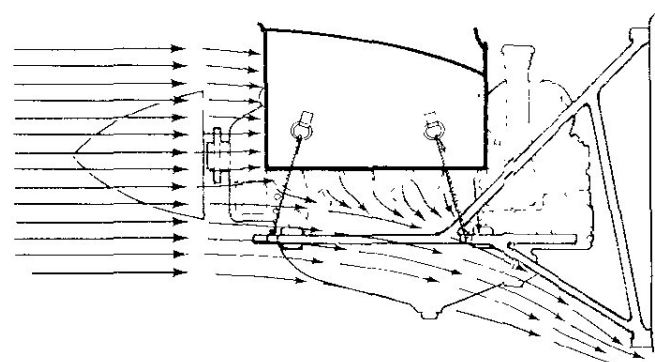


Figure 8. Sheet metal cooling air scoop installed over uncowled engine. Note bungee cords and hooks for holding scoop in place.

ENGINES NEED REGULAR EXERCISE

“Reprinted from Sport Flying Magazine”

My engine needs exercise! Why that’s ridiculous, engines don’t have muscles! Your reaction is quite normal and in fact you’re partly correct. Engines do not have muscles. However your engine does need regular exercise and here’s why.

For this particular subject airplane owners can be divided into two basic categories. Those who fly their airplanes regularly and those who don’t. It’s those who don’t that should keep reading.

No doubt you have heard that time-honored cliché, “You never get something for nothing.” Well, it’s just as true as it ever was and your aircraft engine is an excellent example. The outstanding performance and reliability of the modern aircraft engine is possible only because of its high quality. This old cliché is also influential in the realm of design. Rarely ever will the design engineer find a panacea solution to a design problem. He usually must settle for some compromises in order to get the feature he wants most. This same situation applies to the available materials from which his designs will be constructed. Consequently, the design of your engine and the materials used in its construction are by nature of its mission the best possible solutions.

Finally, the mission of your engine is active service and not an idle potential sitting around for months or years on end. Keep these facts in mind as we examine what can happen to an engine during long periods of inactivity.

A considerable amount of lubrication goes on inside an engine during normal operation. Naturally you want this oil retained within the engine and not “squirting” out of every seam and joint. This simple but important requirement is handled by the use of numerous gaskets and oil seals.

These seals are fabricated from many different materials depending on the conditions under which they must serve. Some types of seals depend on oil wetting to keep them live and in proper condition. Long periods of inactivity can cause these seals to dry out. Consequently, they will allow minor but annoying leaks when service is resumed until they become oil wetted once more.

Rubber seals are also affected by long periods of inactivity. Most rubber seals, such as the ‘O’ ring seal, are installed in a fashion that will provide some initial deformation. It is this deformation or “slight squashing” of the ‘O’ ring that provides the static or “at rest” seal. Under long periods of inactivity, these seals have a tendency to lose their natural resiliency and accept some permanent deformation. Regular normal engine operation tends to retard this condition.

However the most detrimental effects of engine inactivity are “rust” and corrosion damage. There are several factors that contribute to this condition so let’s take one at a time.

You don’t need a degree in chemistry to know that bare metal surfaces are subject to damage from rust and corrosion whenever they are unprotected. The reciprocating aircraft engine contains a considerable number of close tolerance, machined parts. These parts, such as cylinder walls, crankshaft journals, etc. are bare metal and depend upon the protection provided by the lubricating oil.

During normal operation lubricating oil is well distributed throughout the engine, therefore, ample protection will be provided for quite some time after engine shutdown. However, the lubricating oil is a liquid, consequently, it will eventually drain to the lowest point of the area it covered originally. Lubricating oil, like most other liquids, is subject to evaporation.

Consider that after engine shutdown oil distribution throughout the engine ceases. The cylinder walls for example are now protected by the film of oil remaining from distribution prior to shutdown. However this film of oil will thin as the oil drains down to the lower side of the cylinder walls. As this film becomes thinner, the effects of evaporation become greater simply because there is less oil to evaporate. Once the walls become dry they are subject to rust damage from the moisture that is always present in the atmosphere and inside your engine.

Perhaps you are wondering how moisture can get inside your engine when it is all sealed up. It really isn’t all sealed up. In fact it is deliberately vented to the atmosphere because the interior or crankcase of your engine must be able to breathe. As the temperature rises during the day, it causes the air to expand. Therefore, the air inside the crankcase will also expand and breathe outward through the crankcase breather. The reverse will be true as the ambient temperature falls in the evening. Consequently the crankcase will now breathe in. Each time this breathing happens additional moisture and oxygen are drawn into the crankcase. Moisture and oxygen produce rust and corrosion on unprotected, bare metal surfaces.

No attempt should be made to plug or seal this crankcase vent on your engine unless the engine has been properly “pickled” for long term storage. Plugging the crankcase vent on an unpickled engine will only aggravate the moisture problem. By the way, “pickling” is a special and extensive preservation process applied to engines that are to be stored for considerable time.

Another and much greater source of moisture occurs inside your engine each time you start it up and shut it down.

Immediately after start up, moisture will condense on the cold metal parts inside your engine due to the rapid temperature change that is taking place. A good example of this condition is the moisture that forms on the outside of a drinking glass when a cold liquid such as ice tea or beer is poured into it. The same situation can be observed when placing a glass of hot liquid inside a cold refrigerator and this is the same condition that occurs when you shut your engine down. So you see, moisture forms inside your engine during start up and again at shutdown.

Remember too, that the more humid the atmosphere, the more pronounced the moisture situation. Consequently this condition is at its worst along the sea coasts where the humidity is always high and during the summer months for inland areas.

Moisture and oxygen are not the only culprits that cause damage during excessive inactivity. There are also acids and corrosive lead salts produced in the combustion chamber during normal engine operation. Some of these contaminants get into the crankcase by way of "blow by" past the piston rings. Admission of these agents into the crankcase is especially high during starting and ground operation due to low engine temperatures and subsequently greater clearances between pistons and cylinder walls.

If I have made you so nervous that you're ready to rush out and sell your "bird" to the first buyer, relax, because you can easily prevent all of these "catastrophic" culprits from "eating" up your engine. To begin with the conditions described do not take place overnight, but rather over an extended period of time. You are probably wondering when I will get around to telling you just how long your engine can remain safely inactive. I cannot tell you that and I doubt that anyone else can unless they could know exactly the extenuating circumstances involved in each case. For example day to day humidity, time on the lubricating oil, condition of the engine, inside or outside storage, etc.

The simplest and most economical solution requires only two acts on your part. They are one: fly the airplane frequently; two: use the correct grade of a quality brand of lubricating oil and drain it according to the recommendations in your owners manual. I realize that the word "frequently" with regard to flying your airplane sounds like "weazel" wording. However I must remind you of the atmospheric and climatic variables that are always involved. Therefore the suggestions that follow are selected on a basis that will remove doubt and speculation with regard to protection for your engine.

Airplanes based in coastal regions, both seaboard and inland should be flown for at least thirty minutes at cruise once every seven days. This rule will also apply to airplanes based in the deep south during the summer months when the humidity is quite high.

Thirty minutes at cruise power every two weeks should be sufficient for airplanes based inland or where the humidity is less than 70%. In desert regions, you could extend this period even more but then you invite the usual scuffing damage associated with "dry starts". If you really want to do

right by your engine, avoid leaving it stand idle for more than seven days regardless of where it is based.

A "time honored" practice among pilots that care about their engines is weekly run up during periods of inactivity.

Although engine manufacturers appreciate this concern for their engine, this practice is more detrimental than doing nothing at all. Each time the engine is run up and shutdown more water is formed inside the engine. Ground run up never gets the engine hot enough to dry out the oil. Consequently the water contamination continuously increases. Besides the practice constitutes excessive ground operation which is equally undesirable. Ground operation of an aircraft engine should always be held to the absolute minimum if long service life is to be realized.

The lubricating oil in your engine is also employed as a cooling medium. For example, the under side of the pistons get well above the boiling point of water during normal cruise flight. Lubricating oil is thrown or sprayed on the underside of the pistons to keep temperatures within desirable limits. Under these circumstances water will quickly turn to steam and once it becomes a vapor, it will be expelled through the crankcase breather. Usually thirty minutes at cruise power is sufficient to completely dry out the lubricating oil. You cannot determine that the oil temperature you read on the gauge is taken as the oil leaves the sump or after it has passed through the cooling radiator.

In summation, normal ground run-up is not sufficient to dry out the lubricating oil and no attempt should ever be made to get your engine hot enough on the ground.

Equally undesirable is the practice of "doping" the lubricating oil with various additives in the interest of protecting the engine during long periods of inactivity. Only approved corrosion preventive compounds will perform satisfactorily and even then only if the engine is properly "pickled".

Name brand lubricating oils already contain sufficient additives for normal operation. "Doping" the oil with additional additives is about as practical for your engine as it would be for you to prescribe your own medicine.

Another practice consists of pulling the propeller through for several revolutions every week or so. This practice re-distributes the small amount of oil that tends to remain between the pistons and cylinder walls. There is no guarantee however that this procedure will re-oil all of the exposed metal surfaces in your engine and in time the re-distributed oil will also drain away leaving you with nothing to re-distribute.

Your schedule may be so demanding that you cannot always fly your "bird" to keep it active. You might select a pilot friend you can trust and check him out in your machine so that he or she can fly it occasionally. Between the two of you, it shouldn't be much of a problem to fly it for thirty minutes several times a month. This regular exercise will help retain your engine's mechanical health, and don't forget the oil. Use a good brand of lubricating oil and change it frequently.

ENGINE OIL CHANGES ARE NECESSARY

“Reprinted from Sport Flying Magazine”

Periodic oil changes are the most economical maintenance you can buy for your engine. Therefore oil changes are absolutely necessary.

I doubt if there is a pilot anywhere who hasn't been confronted with this subject and the controversial confusion surrounding it.

I believe that the average aircraft owner cares about his engine and wants to do right by it. However when one considers the amount of controversial information on just one aspect of engine maintenance, it isn't any wonder that the owner can be confused or misled. Therefore he deserves an explanation regarding the “Why's and Wherefore's” of periodic oil change.

OIL'S 5 FUNCTIONS

The lubricating oil in your engine does considerably more than reduce friction. In fact it performs five major functions all of which are necessary requirements. Each of these five basic requirements must be met to the degree specified by the engine manufacturer before the oil can be approved for use. You should be aware of these five requirements because they will play an important part in helping you to discriminate between fact and misconception. They are as follows:

1. Reduce friction between moving parts to a negligible amount.
2. Provide necessary cooling to the internal areas of the engine that cannot be reached by external means.
3. Cushion moving parts against shock and help seal the piston rings to cylinder walls.
4. Protect the highly finished internal parts of the engine from rust and corrosion.
5. Keep the interior of the engine clean and free of sludge, dirt, varnish and other harmful contaminants.

OIL WEARS OUT

The lubricating oil must perform all five of these functions simultaneously and without compromise among any of the five functions. Therefore the oil must have a high degree of compatibility between each of its five functions so that each will function as required without impairing any of the others. That's no small task and to do all of that it has to be more than just plain oil. Since each of these five functions has a definite influence on when the oil shall be changed, let's examine each one separately. In each of these five functions we have the behavior of the oil in performing its function and the subsequent effects imposed upon it by the engine.

1. *Reduce Friction* – During normal operation lubricating oil is distributed to all moving parts in the engine. The method of delivery, quantity and pressure vary according to the loads imposed on the various parts. In all cases however the oil reduces friction by behaving like millions of “tiny ball bearings” rolling around between the moving parts of the engine. In a sense these “little ball bearings” of oil can be regulated in size by the petroleum refineries. Thus the different viscosities or grades of lubricating oils that are available.

The clearances or space between moving parts in your engine dictate what grade or viscosity of oil the engine must have in order to provide satisfactory operation and a long service life.

Now let's examine the effects imposed upon the oil by the engine. No doubt you have heard that old statement, “Oil does not wear out.” Well the truth of this misconception is that oil does wear out. Today's high compression engines subject their lubricating oils to severe stresses and in more ways than one. Actual laboratory tests have shown conclusively shearing action from many of the moving parts in the engine. In time this shearing action will alter the oils original viscosity properties. The petroleum engineers call this a change in the oil's “thixotropic” properties. That “two dollar” word simply means the oil “isn't what it used to be.” Once this happens to the oil. Its continued use could lead to a reduction in service life of the engine. This same condition was also observed in oil samples taken from actual engines in regular normal service. Remember that “this tired” condition of the lubricating oil is a product of continued normal engine operation.

2. *Provide necessary cooling* – Moving parts generate friction which in turn produces heat. While the lubricating oil practically eliminates metal to metal contact, it is subject to its own friction. The constant flow of oil to all of these moving parts carries away the heat fast enough to keep the operating parts at a safe temperature. The upper cylinder walls, pistons and exhaust valve stems are exposed to extreme temperatures during normal combustion. Here again the excess heat inside the engine is removed by the lubricating oil.

Keep in mind that the oil temperature you see on the instrument panel is the temperature of the oil after it leaves the oil cooling radiator. Engines not equipped with oil radiators usually have their oil temperature taken immediately after the oil is removed from the sump where it has time to cool before redistribution. Here again the oil temperature is considerably less than what it is during actual contact with the hot parts.

I would like to caution the reader at this point not to draw the conclusion that the cooler he runs his oil temperatures, the better for the oil and the engine. Too low an oil temperature can be harmful to the engine because then the oil will not get hot enough to dry out the moisture that it collects during normal shutdown and start up.

The "hot" areas of the engine and turbo-charger impose high temperatures on the lubricating oil while it is performing its cooling function. These high temperatures subject the oil to "coking" and "oxidation." Coking tends to dirty up the oil with carbon particles while oxidation causes the oil to break down and thicken. A "full flow" filter will help to remove much of the coking effects but nothing can be done about the oxidation. Both of these effects are harmful destruction of the oil and if you persist in running past the manufacturers recommended time between changes, you are just "begging" for trouble.

3. *Cushioning and sealing* – A good example of cushioning is in the valve train. Here each valve is being "thrust" open and "yanked" shut every 1/20th of a second at normal cruise power. Imagine how long these parts would last if it were not for the shock absorbing qualities of the oil film between these parts. A thin film of oil on the cylinder walls not only lubricates but helps provide the necessary gas tight seal between the piston rings and cylinder walls.

In this function one can easily see the severe shearing and crushing action imposed on the lubricating oil by just the valve train alone. Also a perfect gas tight seal between piston rings and cylinder walls is never completely attained so the lubricating oil will be subjected to some high temperature "blow by" of combustion gasses. Not only does this "blow by" contribute to the oxidation situation pointed out earlier but it also contaminates the oil with various acids and corrosive lead salts generated during combustion. These contaminants remain in the oil and are not removed by the filter. Each hour of engine operation adds more of these contaminants. After shut-down, water vapor condenses inside the engine and its subsequent mixture with these corrosive combustion products produces harmful acids.

4. *Preservation* – The lubricating oil accomplishes this task in several ways. After engine shutdown a coating of oil covers all of the interior of the engine. This coating provides protection against rust, however it will slowly drain off in time and eventually expose the interior of the engine to rust damage. In order to maintain this protection the engine should be flown (not run up) at least once a month, inland and every two weeks, sea coast. Additives in the lubricating oil provide some protection against corrosion, however these additives are not sufficient for long periods of engine idleness.

Remember that during normal operation the engine continuously adds more contaminants to the lubricating oil. In time the protective additives will be used up and the oil becomes saturated with undesirable corrosive agents. The only certain continued protection is changing oil.

5. *Interior cleanliness* – Ashless dispersant type lubricating oils will keep the interior of your engine clean if used continuously after the first 100 hours of the engine's life. These oils contain additives that cause the dirt to disperse throughout the oil and also to prevent the dirt from

precipitating out of the oil and collecting in the engine when the oil is at rest. This function is vitally important since there are many oil passages in an engine that could be clogged up in time with dirt and cause oil starvation. Also there are many assemblies such as hydraulic valve lifters that must have clean oil for their satisfactory operation otherwise they will fill up with dirt and sludge and cease to operate.

Every hour the engine runs it adds more dirt to the oil.. This dirt comes from a variety of places. Dust taken from the atmosphere which is always present even at high altitudes. Also from soot during starting and idling. Then there is the "coke" produced by the "hot" areas. Highly corrosive lead salts and minute metal particles are other sources. "Blow by" gasses contribute several different acids such as sulfuric, formic and others. Water vapor forms each time the engine is shutdown and started up. Gasoline dilution occurs during starting especially during cold weather. When all of this "garbage" gets mixed up in your lubricating oil, it forms some new contaminates of its own such as sludge, varnish, and highly corrosive acids. Acids are usually harmful only when they are wet or contain water. When the lubricating oil reaches its normal operating temperature, it will "dry out." The water is vaporized and passes out through the crankcase breather during "dry out" of the oil, but remember, after shutdown it will return and during the humid summer months this condition is worse than any other time of the year. The more humid the climate, the more water condensation during shutdown and start up. All airplane engines are not equipped with "full flow" filters, but even those having filters do not enjoy all the protection some owners are often led to believe. The filter can remove only the solid contaminants such as, dirt and coke. The liquid contaminants pass right through the filter and continue to remain in the oil. The only way to get rid of them is to drain the oil.

DIRT YOUR ENEMY

Well, there you have the story of what the lubricating oil does in your engine and what your engine does to the lubricating oil. One of your engine's worst enemies is dirty, contaminated lubricating oil. A badly worn bearing is a typical example of what happens if your engine is operated with dirty oil.

If your engine does not have a full flow filter, the oil should be changed more often and for good reason. Only a small amount of dirt entering your engine can ruin it. How does it get in? the engine "breathes" it into its cylinders. What about the air filter you say? Yes, if the air filter is properly serviced and replaced when necessary, it will keep most of the dirt out but some does get in and finds its way into the oil. There is considerably more dirt and dust in the atmosphere than you may realize.

THE NEW ENGINE

While we are on the subject of oil changes let's examine a few other wide-spread misconceptions. One of these involves the type of oil to be used in breaking in a new aircraft engine. To start with, your new or remanufactured

zero time engine is already broken in when you receive it. Every engine is run on a test stand until it is broken in. However the first 100 hours of this engine's life are considered the final running in period.

During the first 50 hours of operation only straight, petroleum mineral oil should be used. This type of oil does not have the special additives found in ashless dispersant or detergent types. There is nothing special about this oil, it is simply a petroleum base lubricating oil. Because it does not contain the "super lubricants" present in the ashless dispersant oils, it will permit the minute film ruptures necessary to obtain the desired piston ring to cylinder wall contact during the initial running in period. This is the same type oil used during the break in on the test stand.

The use of additive oils could result in failure of the engine to successfully complete its final piston ring seating during that first 50 hours. We know of cases where the owner followed our recommendations and then added one of those "super friction proofing" additives to the mineral oil. He meant well because he thought he was helping his engine through that first 50 hours. If you want your engine to "seat in" properly, this is exactly what you don't do.

Usually the first 50 hours of operation will be adequate for proper ring seating. From then on we recommend that you use only an ashless dispersant oil for the rest of the engine's life.

MIXED BRANDS OK

Another popular misconception is that lubricating oil from different name brand refineries should not be mixed. This is not so at all. For example, you're flying cross country during your engine's first 50 hours and the straight mineral in your engine is brand T. The field where you landed has only brand S in straight mineral oil and you need a quart. Add a quart of brand S. No harm will result because they will mix quite satisfactorily.

The same rule applies if you're past the 50 hour mark and running on an ashless dispersant oil. Different name brands of ashless dispersant will mix with each other equally satisfactorily. We continue to recommend that you pick a "name brand" and stay with it, however no harm is going to result if you should have to add another name brand of the same type and grade during your cross country travels. Despite what the skeptics may tell you, no major petroleum company is about to market an aircraft engine lubricating oil that isn't compatible with other brands on the market.

Another situation that we encounter is the use of automotive detergent oil in aircraft engines. This is a no-no

from either side. Don't use automotive oils of any kind in your aircraft engine. Automotive oils are refined specifically for the lower temperature operation encountered in the water cooled automotive engine. These oils contain metallic ash additives that could cause pre-ignition in an air cooled aviation engine. This is no reflection on the quality of automotive oils. By the same token, aircraft oil should not ever be used in automobile engines because it is not suited for this type of operation.

ADDITIVES NOT NECESSARY

Then there is the popular "owner fad" of adding "super lubricants" to his engine oil. Of course the owner does this in complete sincerity that he is making life easier for his engine and prolonging its life. Believe me, the engine manufacturers appreciate owners like this that really care about their engines but we also want his engine to operate economically for him as well as providing a long service life. Let's examine a few facts on this subject.

First of all the engine's bearings are designed in excess of the loads they must carry even at peak power, so the engine is never really straining when it is being operated properly. Second the modern ashless dispersant lubricating oils are more than adequate for the task they perform. They are so capable of reducing friction and resisting film rupture that for this very reason we prefer that you don't use them during the first 50 hours of run in operation. These oils already have "super lubricant" additives blended into them at the refinery. That old saying "if a little does so much good, think what a lot would do!" isn't always applicable. A spoon full of castor oil does wonders for certain needs and yet you wouldn't drink the whole bottle on the basis of the "old saying." A good brand of ashless dispersant lubricating oil changed on schedule is quite satisfactory and that is all that we recommend.

Many times we are asked what brand of oil do we prefer or recommend. We have no particular preference and we recommend any of the brands specified in Continental Motors bulletin MHS-24A. We do recommend that you change oil at the first 50 hours, filter or not. Remember, the filter removes only the solids, not the liquid contaminants. Above all whatever your choice of engine may be, it is you who keeps that engine manufacturer in business, therefore he is not about to advise you wrong. **DO CHANGE LUBRICATING OIL AS RECOMMENDED, OIL CHANGES ARE NECESSARY!**

IS PREVENTIVE MAINTENANCE WORTH IT?

“Reprinted from Airport Services Management Magazine”

Is so called “preventive maintenance” really worth it? Does it really do any good considering the cost and all? I have a friend who buys a new car every couple of years and he never does anything to them; he doesn’t even have them greased or the oil changed. All he does is put in gas and drive them. He never has a minute’s trouble.

When you consider all the extra safety features and quality built into an airplane, plus the fact that it doesn’t have to operate on muddy, salted streets, one wonders about the necessity of any preventive maintenance. Nevertheless the average airplane owner is prone to at least two fallacies when it comes to maintenance on his airplane.

One is the natural tendency to equate the maintenance of his airplane to the stock automobile. The other is listening and in some instances believing those who pass themselves off as experts on the subject.

But even the most stubborn skeptic will have to concede that the best machines are susceptible to damage from abuse and neglect. Trouble-free operation from machinery with no consideration given to maintenance is wishful mythology. Even if every pilot was a qualified expert and did everything perfectly, he still could avoid maintenance.

Misconceptions

There are no aircraft or engines that are fabricated from metals that are completely indestructible – metals that cannot wear, rust, burn, corrode or fail structurally. Nor have we found any rubber or plastic materials that are indestructible, rubber that cannot age or deteriorate, or plastic that will not break or deform.

The tendency to compare aircraft with automobiles is misleading for a second important reason. They are operated in totally different environs. The typical stock car is seldom required to deliver even 70 percent of its rated horsepower on a prolonged basis under normal driving conditions. But an airplane uses all of its power on every takeoff. Unlike the car, losses of power due to the lack of required maintenance will noticeably affect the airplane’s performance, especially under gross load or short runway conditions.

Cars are not required to pass from hot to cold temperatures within a matter of minutes, but a turbosupercharged aircraft is often required to climb from a surface temperature of 100 degrees F or more to a minus 12 degrees F at 20,000 feet in less than 15 minutes.

These are only some of the many differences that void any comparison between aircraft and car, particularly when maintenance requirements are taken into consideration.

The third factor is equally important and consists of reasonable explanation to the owner of exactly what “preventative maintenance” is in terms of value to him. Attempting to badger the owner into accepting preventive maintenance with high pressure selling, threats or warranty nullification or FAA mandates is not a satisfactory approach.

Cost Considerations

The factor of most concern to the airplane owners is the cost involved. You must be able to prove to his satisfaction that proper preventative maintenance will cost him less over the period that he owns the airplane than going the route of neglect.

Every twelve months the airplane must pass a thorough and rigid inspection before its license can be renewed. We all know this, including the owner. This is one of the areas in which to prove the economy of preventive maintenance.

Let’s say we have an owner who flies 350 hours a year and his airplane is in the shop only when some malfunction occurs, or once a year for its annual. During the inspection the mechanic finds a badly leaking exhaust gasket at one of the cylinder heads.

Closer examination reveals that the gasket has been leaking for a considerable number of hours. The result is a cylinder head damaged beyond use. The cost: \$480.00 for a new cylinder barrel and head assembly and this doesn’t include any of the other incidentals or labor. The total bill will be in excess of \$600.00 just for parts and labor.

Would preventative maintenance have cost this much? Definitely not. Would it have prevented this damage? The answer is yes. In this particular case it was pointed out to the customer that this condition would have been detected during a regular oil change. But this owner changes the oil himself because he saves money. One wonders how much he saved in neglect after the cost of repairs resulting from neglect were deducted.

Another area of neglect that can cause expensive repercussions is induction air filter maintenance. The air filter on the average aircraft engine has nowhere near the excess capacity for holding dirt that its counterpart on the automobile has. Consequently it will require more frequent servicing. It should be serviced every 100 hours or more often in dusty operation.

Failure to do so will result in a loss of power and this condition will increase as the filter continues to load up. A dirty air filter will cause excessively rich mixtures which in turn will foul spark plugs and lead to carbon build-up in the combustion chamber. The oil wetted type air filters can be serviced several times before replacement becomes necessary. This is also true of some of the dry paper types.

At any rate, the filter should be serviced as often as its condition dictates and replaced immediately if it shows any signs of deterioration. Failure to heed this advice will surely result in a premature engine overhaul.

Dust and Oil

Many pilots believe that dust exists only near the surface and that once aloft they are out of it. Also, many owners are led down the road of neglect on the basis of misconceptions they have come by one way or another and dust is a good example.

Perhaps the most classic of all examples is engine lubricating oils. So many wild and conflicting beliefs surround this subject that one wonders if there exists a single owner who isn't confused. There are five basic requirements that a lubricating oil must fulfill in the reciprocating aircraft engine. They are in their order of importance as follows:

- Reduce adequate cooling of internal parts.
- Provide adequate cooling of internal parts.
- Help seal piston rings to cylinder walls and cushion moving parts against shock.
- Preservation from rust and corrosion damage to all internal engine parts.
- Keep the interior of the engine clean and free of dirt, sludge, varnish and other harmful contaminants.

The lubricating oil must be capable of performing all five of these functions and with a degree of compatibility that will not force undesirable compromises among any one of these five. To do all of that, it has to be more than just oil. In fact the rule played by modern lubricating oils within the reciprocating engine is so significant that it is difficult to imagine that any usually because of misconceptions.

One common misconception is that oil does not wear out. In fact there was at one time a government bulletin that so stated. Today we know that oil does indeed wear out. The constant and brutal shearing action to which oil is subjected during normal engine operation will in time break down its molecular structure.

Under these conditions and depending on the type of oil, it could be getting thicker or thinner. If this is true, how then can it continue to perform function number one on a satisfactory basis, or function number three? Are you willing to take the chance?

Then there is preservation. Gasoline burning in the combustion chamber of an engine produces various acids. Most of these acids are expelled through the exhaust valve, but not all. Some of each find their way into the lubricating oil through "blow by" past the piston rings and exhaust valve guides. There are other corrosive exhaust products in addition to the acids. However they don't cause any appreciable harm while the engine is operating normally because they are in an antihydrous state. This simply means

that water is not present in their make-up and without water, they are no threat.

Once the engine is shutdown and begins to cool, water vapor in the atmosphere will condense on the surfaces inside the engine. The water droplets run down into the oil and, being heavier, sink into the oil. As the water passes through the oil it comes into contact with the acids mentioned previously. Now destructive acid, activated by the presence of water, forms. Before the acids can cause harm they are neutralized by additives blended into your oil at the refinery.

Each time your engine is started up and shutdown this process is repeated and as long as the additives last you are protected. But that's just it. These additives will in time be consumed and then your protection ends, costing you function number four. Still willing to take the risk?

How about function number five? Even if your engine is equipped with an oil filter it will only remove the harmful solids and not the liquid contaminants. Once your oil reaches the saturation point for dirt and liquid contaminants, it will permit additional contaminants to precipitate out and settle into the engine. When you finally do change oil the excess contaminants will remain in the engine. Failure to change oil at the proper interval can eventually reach a point where your oil isn't even performing half of the required functions. It's difficult to imagine that anyone would jeopardize an \$8,000.00 investment in his powerplant for less than \$10.00 worth of oil.

When to Change

How can the owner be certain of when to change his oil? Simple! Follow the manufacturer's recommendations. I don't know of one airframe or engine manufacturer who isn't concerned with customer satisfaction. Therefore, their recommendations concerning preventative maintenance and that's exactly what an oil change is – are based on actual operating experience, backed with the engineering that conceived the machine in the first place.

Many of the aspects of preventative maintenance are small in comparison to the trouble they can prevent. A good example of this is magneto timing and worn out spark plugs. Improper ignition timing and worn out spark plugs can cause pre-ignition and the owner will seldom be aware until the damage is already an expensive reality.

I know of more than one case where the shop recommended new spark plugs and the owner refused because the engine was running fine on the plugs presently installed. The plugs' ability to fire is only part of the story. If the core nose insulation has deteriorated to where it isn't conducting the heat away from the electrodes and into the cylinder head fast enough, the electrodes can reach temperatures that will introduce pre-ignition. Detection of this condition before it causes trouble is another facet of preventative maintenance. How many sets of spark plugs do you suppose this damage would have paid for?

Good Investment

Records and experience prove beyond any doubt that insufficient maintenance costs more than preventative

maintenance. In addition to offering the owner lower overall maintenance cost for his aircraft, preventative maintenance also keeps his “bird” in top operating performance, assures him of the safety and reliability built into his machine and protects the top retain value of his investment.

Some owners hold the misconception that preventative maintenance is a scheme dreamed up by the fixed base operators and franchised dealers for increasing revenue from their shops. Nothing could be further from the truth. The aircraft and engine manufacturers are the progenitors of the recommended preventative maintenance for their products and for a very good reason.

I repeat, I don’t know of a single aircraft or powerplant manufacturer that isn’t interested in customer satisfaction. This preventative maintenance schedules developed by the manufacturer are designed to give the owner the longest possible service life at the lowest possible cost. When one considers that all of these manufacturers are constantly competing with each other to win that individual owner, it would be absurd to believe anything else.

Handling Customers

However don’t expect much owner reaction from statements like “because the factory said so, that’s why”.

Many owners never see a manual, but you do. If they are skeptical, show them the preventative maintenance schedule set forth in the service manual for their aircraft or engines. Remember too, that once you have won them over, you have an obligation to them.

Don’t pass “mistakes or bloopers” off on the customer’s bill; they should always be your responsibility. A maintenance facility that passes excess charges on to the owner because of its own shortcomings, whatever they may be, will destroy owner confidence in that facility. This sort of thing will never encourage a belief in preventative maintenance.

No one is ever permanently sold. You must continue to sell him on preventative maintenance each time it is performed. He is just like you in that he doesn’t have money to waste and he likes and wants to believe that what he is paying is wisely spent. It should be easy for you to promote this feeling. If your customer keeps his bird in “mint” condition, tell him so; he likes to hear it. If you corrected some little situation that would have lead to future trouble, point it out.

But remember, convincing the owner of the merits of preventative maintenance is only the beginning. It is you who must keep him sold!

YOUR ENGINE’S HEALTH

Some of the most frequent questions that are encountered during pilot seminars and in letters, concern engine health. For example, “How can I tell if my engine is in good health?”, “When should I consider that my engine is not safe enough to continue on to the recommended TBO?” and so on. Such questions are very realistic and therefore deserve practical answers.

Let’s begin with where the responsibility for engine health lies. Many owners honestly believe that such responsibility belongs to their dealer or mechanic. The hard truth of the matter is that such responsibility rests solely with the aircraft owner and no one else. The mechanic is responsible only for the work that he performs. Acceptance by the airplane owner of this responsibility is the first step in ascertaining and maintaining engine health.

The second step should be locating a competent and reliable service facility or certificated A & P mechanic. Once this step is established the owner has only to follow the recommendations set forth in his engine and/or airframe owner’s manuals. While it is not mandatory for privately owned and operated aircraft, Teledyne Continental Motors recommend that you have a factory prescribed 100 hour inspection performed on your engine each 100 hours of operation. Between 100 hour inspections maintenance items like oil and oil filter changes, induction air filter service, etc. should be accomplished as recommended and even more often where necessary. In addition to these steps the owner

should immediately be suspicious of any unusual or abnormal operation of his engine and discuss it with his mechanic as soon as possible. Don’t wait until the next 100 hour inspection. Often troubles can be located and corrected quickly with modest cost. To delay could be much more expensive and even dangerous. The most important point in this second step is to believe and follow the recommendations of your service facility or mechanic.

Engine health rarely deteriorates rapidly, it is more often a gradual process. The owner or pilot is in the best position to monitor the symptoms of deteriorating engine health and subsequently communicate the symptoms to his mechanic for proper diagnosis. The owner, unless a qualified A & P mechanic, should not attempt such diagnosis himself. Engines, like people, sometimes produce misleading symptoms that tend to indicate one kind of problem when it is actually something else. The experienced mechanic is a specialist and he has the tools and equipment to help him arrive at an accurate diagnosis. However the pilot should be able to recognize the major symptoms of deteriorating engine health, and here are a few examples.

One of the foremost symptoms of failing health is an increase in oil consumption. A gradual increase in oil consumption usually indicates piston ring, cylinder wall and valve guide wear. This tells you that your engine is approaching a top overhaul.

The top spark plugs will help indicate ring, cylinder and valve guide wear. After a long cross country flight of 65% power or more, land and taxi in with as little low power and ground running as possible. Remove all top spark plugs and examine them for signs of oil wetness. Under normal operation, the top spark plugs should be dry

. When all top plugs show oil wetness, you can be fairly certain that excessive wear is present in all cylinders and this will usually include the guides. This condition tells you it's time to overhaul. If the engine is within a few hundred hours of its suggested TBO it will be more practical to major it, otherwise a top overhaul is in order.

A sudden increase in oil consumption is a different story and usually indicates some sort of malfunction or even a part failure such as a broken piston ring. If missing and roughness are also present it could mean a burned piston. At any rate the actual diagnosis should be left to an experienced mechanic.

Another symptom of imminent major overhaul is a rough and noisy engine. Wear increases clearances between moving parts causing vibration and an increase in noise. Such a symptom is difficult to detect by the person flying the airplane on a regular basis because it develops so gradually that he is accustomed to it. However it will be apparent to another experienced pilot flying the airplane for the first time. This condition is usually prevalent in engines that are operated well past the manufacturer's recommended TBO. This condition is usually accompanied with excessive oil consumption. However that may not always be true., For example a particular engine has a recommended TBO of 1800 hours. The engine was running so well at 1800 hours that the owner decided to top it rather than major it. Under normal conditions a properly executed top overhaul could go another 1800 hours, but there is no guarantee that all of the other parts subject to wear will continue properly for that long. Consequently as the engine progresses beyond its recommended TBO it may gradually become rough and noisy while oil consumption remains normal.

Another good indication of health problems is excessive magneto drops due to fouled spark plugs. In normal operation a spark plug is self cleaning.

A tremendous amount of technology is involved in the development of a spark plug, and still more effort is involved in selecting the correct spark plug, and still more effort is involved in selecting the correct spark plug for your engine. In fact it is actually in violation of FAA regulations to use any other spark plugs but those specified for your engine by its respective manufacturer. Consequently excessive spark plug fouling indicates a malfunction or improper engine operating procedures.

Most common is lead fouling. Under this condition the core nose insulator and surrounding area of the spark plug will display tan colored deposits that are usually globular in appearance. A certain amount of this condition is normal and not enough to cause trouble or require frequent plug cleaning. Excessive lead fouling to the extent that plug removal and cleaning becomes necessary is nearly always caused by improper engine operation or excessive use of higher octane fuel than specified for your engine.

Consequently lead fouling is not an indicator of poor or deteriorating engine health.

Fuel fouling shows up in the form of dark black, sooty looking deposit. When spark plugs show this condition, they indicate considerable operation with excessively rich mixtures. This could be due to insufficient leaning during high altitude flights. However it is more often due to overly rich idle mixtures, excessive ground operation and long power off let downs from altitude with the mixture in full rich. When this shows up only on one bank of cylinders it signals distribution problems in your engine. This could be due to defective carburetion or injection malfunction. Again this is not an indication of engine health, but rather a warning of improper operation due to malfunctioning fuel metering equipment or improper procedures with the mixture control.

Another warning given by your spark plugs is excessive lean mixtures. Under this condition the top spark plugs will be very clean with only a white, powder like appearance. If the bottom plugs look very nearly the same, you are operating too lean and a premature top overhaul will be just around the corner. If this condition shows up on both plugs, but only on one bank of cylinders it usually indicates mechanical difficulties such as, an induction air leak on that side, carburetion or fuel injection difficulties. If it appears on both plugs from just one cylinder, a partially plugged fuel injection nozzle is likely the culprit. Whatever the cause, it must be located and corrected at once otherwise engine damage will surely result.

Oil fouling is somewhat similar to fuel fouling in appearance. Under this condition the deposits will be more of a faded black and of course, always wet. A small amount of this condition on the bottom plugs will be normal especially on high time engines. When it begins to appear on the top plugs, coupled with increasing oil consumption, its time to overhaul. If this condition shows up on only one cylinder it is an indication of distress in that particular cylinder, such as broken rings for example. Oil wetted plugs on a turbocharged engine could also be indication of oil passage from the turbocharger into the compressor due to bearing or seal distress in the turbocharger.

The engines lubricating system provides several indications of engine health. The main oil screen for example. This screen should be removed, examined and cleaned with each oil change. Under normal operating conditions this screen should contain only small amounts of carbon particles and perhaps some traces of lint and metal particles. Any unusual amount of metal in the oil screen is an indication of trouble and should be investigated by a mechanic immediately. Excessive carbon deposits in the oil screen can be an indication of deteriorating engine health. Such a condition usually indicates insufficient oil changes. It can also be an indication of excessive overheating or near red line operating conditions. Whatever the cause, the presence of excessive carbon in the oil screens is nearly always a forewarning of stuck or approaching stuck piston rings. If this condition is accompanied by excessive oil consumption, it is almost certain that the rings are already stuck.

Oil pressure can also be used to determine deterioration of engine health. Oil pressure is nothing more than the sum total of resistance encountered by the flow of oil through the lubricating system. As wear increases the clearances between moving parts, the resistance to oil flow will decrease. Consequently the pressure at both idle and normal cruise power will gradually decrease over a period of engine hours. A properly operated engine that has received adequate maintenance and oil changes usually won't experience noticeable diminishing oil pressure until very near major overhaul or possibly even well past the recommended TBO. Consequently regard such an indication as advance warning and make it known to your mechanic.

All engines are assigned a recommended TBO (Time Between Overhaul) and this assigned number of hours applies to major overhaul, not top overhauls. The assigned number of hours is predicated on actual field experience with that particular engine in service. While it is possible that under certain conditions you may find it necessary to top overhaul the engine before the TBO is reached, most engines do reach their assigned TBO and in many cases the engine is still in very good health. The owner may be reluctant to overhaul an engine that is running well and is in good health despite the fact that it has reached its TBO. Under such circumstances he has the option to continue operating the engine on 100 hour increments for as long as

the engine remains in satisfactory health, and that state of health is also verified in the engine's log book by a Certified A & P mechanic. However keep in mind that such operation involves some guess work as you are now past the number of hours of known experience. Also the rate of wear increases with wear. This means that the wear rate will be much faster on an engine past 1500 hours as compared to 800 to 1200 hours. Consequently running well past the recommended TBO could result in a much more expensive overhaul than if it had been overhauled at the recommended TBO.

In addition to being able to determine engine health there are a few very important measures that the owner can take to help assure his engine's health.

1. Avoid excessive (a week or more) periods of inactivity.
2. Use a good grade of lubricating oil and change it as often as recommended in your Owner's Manual or more often when necessary.
3. Keep the induction air filter clean at all times and replace it at first signs of deteriorating efficiency.
4. Avoid excessive ground running and especially during hot (+90 and above) weather.
5. Maintain sufficient airspeed during climb to provide adequate engine cooling, especially during hot weather.
6. Be generous with the mixture control, especially at high power settings.

BACK TO BASICS ENGINE INSTRUMENTS

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Aside from the principal engine instruments, which register rpm and manifold pressure, and which were the subject of an earlier article in this series (December 1969), there are several other engine instruments the small size and frequently inconspicuous position of which make us prone to ignore them. These are the oil-pressure, oil-temperature, fuel-pressure and cylinder-head-temperature gauges. All four commonly give the same monotonous indications from day to day, until we barely notice them any more – or until we notice with a start, often too late, that one or another of them has changed its habits.

All of these instruments are characterized in most modern panels by a green operating range with red lines at either end. In general, any steady indication in the green is a good sign of good functioning: any unexpected fluctuation is a sign of possible trouble. As always, a bad indication may be instrument trouble rather than engine trouble, and if one gauge acts up when everything else is perfectly normal, and everything sounds and feels normal, then the gauge is telling the truth, and to act accordingly.

Though the basic message of an unusual instrument indication is usually "land", it may be possible with a sufficient understanding of the engine and how its

instrumentation works to judge how urgent the advice is, what the reason for it is, and what action should be taken on the ground to set things right again.

The primary function of the oil-pressure gauge is to inform the pilot that oil pressure exists and that it is within specified limits. The oil pressure is produced by a pump that takes oil from the sump and sends it through a series of passages, called galleries, to the various bearings, sleeves and bushings, which must remain drenched in oil in order to operate properly. Air-cooled engines depend heavily upon their lubricating oil for cooling; heat picked up by the oil on the way through the engine is dissipated either through the sump walls, in small engines, or else in an oil radiator. Sometimes, the flow of oil through the oil radiator is controlled by a thermostat, which operates in the same manner as the thermostat in an automobile radiator. When the coolant (the oil, in this case) is too low a temperature, the thermostat retards the flow through the radiator, reducing heat loss and raising the temperature of the oil.

The system is completed by a pressure-relief valve at the pump end; its purpose is to prevent a pump overload in case of a high resistance in the lubricating system – that caused by closing of the radiator thermostat, for instance.

Oil pressure may be read – “picked off” – either just after the pump, in which case total oil pressure is reported, or just before the sump, in which case residual pressure is read. Typically, a pick-off at the pump end reads a high pressure consistently and gives a nearly instantaneous indication of pressure upon engine starting; however, it is for most purposes less informative than a pick-off midway in the system or at its end. When the pick-off is located near the end of the lubricating system, as on Continental O-300 and O-470 series engines, the gauge indication lags on start-up; but when the pressure comes up, you know that oil has made its way through the entire system and the engine is receiving lubrication. A pick-off at the pump end might be misleading in some cases; for instance, on a very cold engine, congealed oil in the galleries might cause quite a bit of oil to pass through the pressure-relief valve, giving a good pressure indication but no lubrication. The pressure read from a pick-off at the sump end is actually “bonus” pressure – the pressure remaining after most of the engine has received lubrication. If the pressure indicated at normal operating temperature at idle speed is within specified limits, the end pick-off also testifies to the good health of the engine bearings.

Even without knowing the type of pick-off involved, however, the pilot can still learn a lot from his oil-pressure gauge merely by comparing readings from day to day. Sudden abnormally low oil pressure can indicate low oil quantity; this condition is usually accompanied by an abnormal rise in oil temperature. The same symptom might have other meanings, however. Oil pressure will be low, but consistently so, when oil of too low a viscosity is used (30-weight rather than 40 or 50 in warm weather, for instance). A gradual loss of oil pressure over a period of time might indicate clogged filters and screens – a condition usually arising from the operator’s failure to change oil at the prescribed intervals. In extreme cold, engines equipped with thermostatically controlled oil radiators, if improperly winterized, may experience a loss of pressure shortly after take-off, along with rise in oil temperature. If flight is continued, both gauges may eventually reach redline indications. The cause is oil congealed in the radiator, which fails to clear out when the thermostat opens.

Sudden loss of oil pressure could be due to an oil-pressure relief valve sticking open or, in aircraft equipped with oil-dilution systems, to a malfunction or inadvertent actuation of the oil by flooding it with fuel.

Abnormally high oil pressure is unusual. It could be due to oil of too high a viscosity number (most likely), or perhaps to failure of the oil-pressure relief valve to open. Sudden pressure fluctuations can mean that you are running out of oil – because of a rapid leak, if a slow drop in pressure did not occur first – and that the oil pump is beginning to pick up air. It could also mean the pressure-relief valve is alternately sticking and releasing.

Sudden and complete loss of oil pressure is usually an indication of a mechanical failure such as a broken oil line, failed bearing or failed pump. These are all very rare – especially pump failure.

Oil temperature is closely related to oil pressure. Since the engine depends on oil for some of its cooling, oil

temperature is a measure of a vital operation, especially in engines that are not equipped with oil radiators. However, a high oil temperature, as long as it remains within the green, is not cause for alarm. In fact, oil temperatures running consistently low, near the bottom of the green, are more deserving of attention. The reason is that elements other than solid dirt contaminate the oil. Filters remove dirt, but they do not remove liquid contaminants, which only boil off at high temperatures. Consequently low oil temperature may lead to incomplete boil-off of contaminants, which will then rust or corrode internal engine parts. Oil temperature tends to run consistently low in cold-weather operation, especially on engines not equipped with thermostatically controlled oil radiators. When consistent low-temperature operation is unavoidable, the oil should be changed frequently to get rid of the inevitable liquid contaminants.

Periodic oil temperature fluctuations will be observed in engines equipped with oil-radiator thermostats, especially shortly after takeoff and during climb. These fluctuations indicate normal operation of the thermostat. Persistent fluctuation during flight, or consistently low or high oil temperature in fair weather, usually indicates a thermostat malfunction, although a sharply climbing indication in extremely cold weather may rather suggest blockage of the radiator by congealed oil.

High oil temperature may also be due to over – or under-filling of the engine with oil; to excessively high power settings at low air-speeds; to fuel of too low an octane; or to laboring or lugging resulting from using high manifold pressures coupled with low rpm. In the summertime, the air passages through the oil radiator can become plugged with insects, causing excessively high oil temperatures – a condition that a good preflight should preclude. Clogged and dirty oil-filter elements or screens, which retard the flow of oil through the system, also may produce high oil temperatures.

While the oil-temperature gauge does provide valuable information about the thermal balance of the engine, it is comparatively insensitive to rapid changes in temperature in some areas, such as the tops of the cylinders. In order to keep the pilot informed of temperatures in the cylinder heads, a temperature sensor is imbedded in one of the rear cylinders of the engine – usually the one that is assumed to be the hottest-running of all the cylinders. The cylinder head, however, is not the hottest-running part of the engine. The exhaust valves and stacks and the spark plugs run considerably hotter. Nevertheless, the temperature of the cylinder heads can give important information about more than the heads alone.

Usually, an abnormal cylinder-head temperature indication is on the high side. An uncommonly low reading might indicate insufficient winterization, open cowl flaps when they should be closed, or simply insufficient power to keep temperatures up. High temperatures, however, are the important ones.

An abnormally high cylinder-head temperature may, to start with, indicate that the flow of cooling air over the engine is somehow impeded. It may merely be a matter of too much power, too little airspeed and too warm a day, as in a long, steep climb in hot weather. In cold weather, however,

ice can collect on the cooling inlets, constricting airflow. In spring and summer, it is not uncommon to find birds' nests inside the engine cowling on top of the cylinders. Anything – even a scrap of paper blown into the cooling baffles – that impedes airflow around the engine will cause a rise in cylinder-head temperature. At the other extreme, incorrectly installed or missing baffles, by permitting too unrestricted a flow around the engine, may prevent efficient cooling and lead to a rise, not drop, in head temperature.

If the cooling airflow is working as intended, the cause of heating is internal. High readings at cruise power just after a fuel stop could mean that you got fuel of too low an octane for your engine. Excessive temperatures at cruise power immediately after a 100-hour inspection or engine check could indicate improper magneto timing. High manifold pressures combined with low rpm – or any other practice conducive to detonation – will cause high cylinder-head temperatures; operating with an excessively lean mixture is perhaps the most common example. Finally, anything that interferes with the free discharge of exhaust gas will also cause a rise in cylinder-head temperature.

The fuel-pressure gauge can also forewarn of trouble if the pilot is sufficiently familiar with his fuel system to interpret its indications. On engines equipped with carburetors, the pressure gauge is used primarily to indicate that fuel pressure is within the desired operating range. A sudden loss of all fuel pressure followed by return to normal with activation of the auxiliary pump usually indicates a broken fuel line. Under these circumstances, the auxiliary pump should be shut off immediately and the fuel valve set at the "off" position; otherwise, there is a possibility of fire. Fluctuating indications point to a depletion of fuel supply to the pump, which could be caused by a tank running dry, or by leaks or obstructions in the line from the tank to the pump. Upward fluctuations may also indicate an obstruction in the line from the pump to the carburetor; in this case, a sudden high rise in fuel pressure is usually coupled with a loss of power. A sudden drop in fuel pressure coupled with a

loss of power usually reveals a leak between the pump and the carburetor. If these symptoms are followed by a gradual drop in oil pressure, the probable cause is a ruptured diaphragm in the engine-driven fuel pump (which then lets raw fuel into the crankcase, diluting the oil). If a sudden drop in fuel pressure, coupled with loss of power and engine roughness, is alleviated by leaning of the mixture, the problem is a float needle valve stuck open in the carburetor. If in cold weather you experience a gradual drop in fuel pressure and subsequent loss of power, and the situation is not remedied by the auxiliary fuel pump, you can be reasonably sure that the cause is water contamination in the fuel tanks or lines, which is freezing somewhere between the tanks and the pumps. The possibility of this development makes it imperative to drain sumps thoroughly when taking an airplane out of a hangar for a winter flight, or whenever flight in below-freezing temperatures is planned.

The fuel-pressure gauge on a fuel-injection engine is quite another matter. This instrument is intended to be used for monitoring fuel flow with respect to power settings. In supercharged or turbocharged engines, the subject becomes even more complicated. Trouble shooting with the fuel-pressure gauge on injection engines requires an intimate knowledge of the injection system and its operation that is beyond the ken of most laymen, and beyond the scope of this article.

The other simple engine-monitoring instruments, however, may be very useful, both for interpreting an incipient emergency and for preventing one's ever occurring, as long as the pilot understands the function and significance of the gauges, and the systems about which they speak, well enough to make sense of their reports. For his own safety and for the good maintenance of his engine, every airplane owner should familiarize himself sufficiently with his engine's entrails to make the readings on his instrument panel more than merely monotonous mumblings in an unknown tongue.

AIRCRAFT ENGINE STORAGE

Corrosion can be a devastating enemy of aircraft engines – particularly those in planes that are flown infrequently or placed in storage for an extended period of time.

New engines, or those with new or freshly honed cylinders after a top or major overhaul, are of special concern. In areas of high humidity, there have been instances where corrosion has been found in such cylinders after an inactive period of only a few days. Once these cylinders have been operated for approximately 50 hours, the varnish that collects on the cylinder walls offers some protection against this happening.

Obviously, however, proper steps must be taken to preclude the possibility of corrosion at any time. This is

especially important if the aircraft is based near the seacoast, or in areas of high humidity, and is not flown more than once a week.

The best method for preventing corrosion of the cylinders and other internal parts of the engine is to fly the aircraft at least once a week, long enough for the engine to reach normal operating temperatures that will cook out moisture and other by-products of combustion.

The possibility of corrosion can be lessened by rotating the engine by hand (five revolutions) every seven days, if the aircraft cannot be flown during that period. This is more effective than running the engine up on the ground, which

would only compound the problem by introducing condensation.

Aircraft engine storage recommendations are broken down into the following categories: flyable storage (7 to 30 days); temporary storage (up to 90 days); and indefinite storage.

Flyable Storage. If an aircraft is to be stored much longer than a week under normal climatic conditions, and if periodic flying to circulate the oil will not be carried out, it is advisable to prepare the engine for storage in the following manner:

Operate the engine (preferably in flight) until the oil temperature reaches the normal range. Drain the oil supply from the sump as completely as possible, while the engine is still warm, and replace the drain plug.

Fill the sump to the full mark on the dipstick gauge with lubricating oil meeting the requirements of MIL-C-6529, Type II, which will mix with normal oil and provide protection against corrosion.

Run the engine at least five minutes, at a speed between 1,200 and 1,500 rpm, with the oil and cylinder-head temperatures in the normal operating range.

Each seven days during flyable storage, the propeller should be rotated by hand without running the engine. After rotating by hand without running the engine. After rotating the engine six revolutions, stop the propeller 45 degrees to 90 degrees from the position it was in.

Caution: For maximum safety, accomplish engine rotation as follows: (a) Assure magneto switches are "off". (b) Throttle position "closed". (c) Mixture control "idle cutoff". (d) Do not stand within the arc of the propeller blades while turning the propeller.

If at the end of 30 days the aircraft is not to be removed from storage, the engine should be started and run. The preferred method is to fly the aircraft for 30 minutes and up to, but not exceeding, normal oil and cylinder temperatures.

To prepare the aircraft for service, if the engine has a total time of more than 25 hours, the MIL-C-6529 oil should be drained after a ground warmup. Install the engine manufacturer's recommended oil before flight. (MIL-C-6529 is the Teledyne Continental Motors recommended oil for the first 25 hours of flight).

Temporary Storage. To prepare the engine for temporary storage, remove the top spark plug and atomize spray preservative oil (lubricating oil, contact and volatile, corrosion-inhibited, MIL-L-46002, Grade 1) at room temperature, through the upper spark plug hole of each cylinder, with the piston in the down position. Rotate the crankshaft as each pair of cylinders is sprayed. Stop the crankshaft with no piston at top position.

(Approved preservative oils recommended for use in Teledyne Continental engines for temporary storage are MIL-L-46002, Grade 1, oils: Nucle Oil 105; Daubert Chemical Co., 4700 S. Central Ave., Chicago, Ill.; petrotect VA: Pennsylvania Refining Co., Butler, Pa.; Ferro-Gard 1009-G: Ranco Laboratories, Inc., 3617 Brownsville Rd., Pittsburgh, Pa.)

After completing the above, respray each cylinder without rotating the crank. To thoroughly cover all surfaces of the cylinder interior, move the nozzle of the spray gun from the top to the bottom of the cylinder. Then reinstall the spark

plugs. Apply preservative to the engine interior by spraying the specified oil (approximately two ounces) through the oil filler tube.

Seal all engine openings exposed to the atmosphere by using suitable plugs or moisture-resistant tape, and attach red streamers at each point. Engines with propellers installed should have a tag affixed to the propeller in a conspicuous place, with the following notation on the tag: "Do not turn propeller; engine preserved."

To prepare the engine for service after temporary storage, remove seals, tape, paper, and streamers from all openings. With bottom plugs removed, hand-turn the propeller several revolutions to clear excess preservative oil, then reinstall plugs. Conduct the normal startup procedure. Give the aircraft a thorough cleaning, visual inspection, and test flight.

Indefinite Storage. Prior to storage, drain the engine oil and service the engine with a corrosion-preventive mixture. Use lubricating oil, MIL-C-6529, Type II, as mentioned earlier, or formulate the same product by thoroughly mixing one part compound MIL-C-6529, Type I (Esso Rust-Ban 628, Cosmoline No. 1223, or equivalent), with three parts new lubricating oil of the grade recommended for service (all at room temperature). Immediately after servicing with the corrosion-preventive mixture, fly the aircraft for a period of time not to exceed 30 minutes.

At the conclusion of the preservation flight, with the engine operating at 1,200 to 1,500 rpm, inject corrosion-preventive mixture (221°F to 250°F) into the carburetor air intake until heavy smoke comes from the exhaust. Increase the flow sufficiently to stop the engine. Do not turn the propeller after the engine stops.

Remove the top spark plug from each cylinder and spray with corrosion preventive mixture (221°F to 250°F). To thoroughly cover all surfaces of the cylinder interior, move the nozzle of the spray gun from the top to the bottom of the cylinder. If by accident the propeller is rotated following this spraying, respray the cylinders to ensure an unbroken coverage of corrosion preventive mixture on all surfaces. Install protex plugs in each of the top spark plug holes, making sure that each plug is blue in color when installed. Protect and support the spark plug leads with AN-4060-1 protectors.

If the engine is equipped with a pressure type carburetor, preserve this component by the following method. Drain the carburetor by removing the drain and vapor vent plugs from the regulator and fuel control unit. With the mixture control in the "rich" position, inject lubricating oil, Grade 1010, into the fuel inlet, at a pressure not to exceed 10 psi, until oil flows from the vapor vent plugs. Wire the throttle in the open position, place bags of desiccant in the intake, and seal the opening with moisture-resistant paper and tape, or a cover plate.

If the carburetor is removed from the engine, place a bag of desiccant in the throat of the carburetor air adapter. Seal the adapter with moisture-resistant paper and tape, or a cover plate. Also place a bag of desiccant in the exhaust pipes, and seal the openings with moisture resistant tape. Then seal the cold-air inlet to the heater muff with moisture resistant tape, to exclude moisture and foreign objects. The engine breather

should then be sealed by inserting a protex plug in the breather hose and clamping it in place.

Attach a red streamer to each place on the engine where bags of desiccant are placed. Attach red streamers either outside the sealed area with tape, or inside the seal area with safety wire, to prevent wicking of moisture into the sealed area. Finally, all engines preserved for storage should have the propeller placarded with a sign: "Do not turn propeller: engine preserved."

This procedure may be used for indefinite storage, providing the airplane is run up at maximum intervals of 90 days and then reserviced in accordance with the temporary storage requirements.

Aircraft prepared for indefinite storage should have the cylinder protex plugs inspected weekly. The plugs should be changed as soon as their color indicates unsafe conditions of storage. If the dehydrator plugs have changed color in one half or more of the cylinders, all desiccant material in the engine should be replaced.

The cylinder bores of all engines prepared for indefinite storage should be resprayed with corrosion preventive mixture every six months, or more frequently if bore inspection indicates corrosion: has started earlier. Replace all desiccant and protex plugs.

Before spraying, the engines should be inspected for corrosion as follows. Inspect the interior of at least one cylinder on each engine through the spark plug hole. If the

cylinder shows the start of rust, spray it thoroughly with corrosion preventive oil and turn the prop over five or six times, then respray. Remove at least one rocker box cover from each engine and inspect the valve mechanism.

To return the aircraft to service remove the cylinder protex plugs and all paper, tape, and dehydrating agent used to preserve the engine. Drain the corrosion preventive mixture and reservice with recommended lubricating oil.

If the carburetor has been preserved with oil, drain it by removing the drain and vapor vent plugs from the regulator and fuel control unit. With the mixture control in the "rich" position, inject service type gasoline into the fuel inlet, at a pressure not to exceed 10 psi, until all the oil is flushed from the carburetor. Reinstall the carburetor plugs and attach the fuel line.

Rotate the propeller to clear excess preservative oil from the cylinders. Reinstall the spark plugs and battery, and rotate the propeller by hand through all compressions of the engine to check for liquid lock. Reinstall the cowling and start the engine in the normal manner. Give the aircraft a thorough cleaning, visual inspection, and a test flight.

The foregoing are general recommendations for proper engine care. Since local conditions may differ and Teledyne Continental Motors has no control over the application of these recommendations, no warranty against corrosion is intended.