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FLYING 20 CLUB, Inc.

THE CARE AND FEEDING OF LYCOMINGS

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A Presentation to members of the Flying 20 Club

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Hacking Lycomings – Part One

The engines that power our modern light aircraft are designs that date to the 1930s and 1940s. They've been tweaked and refined over the years; they incorporate some more recent metallurgical advances, but they are dinosaurs by comparison to the engines that power our modern autos.

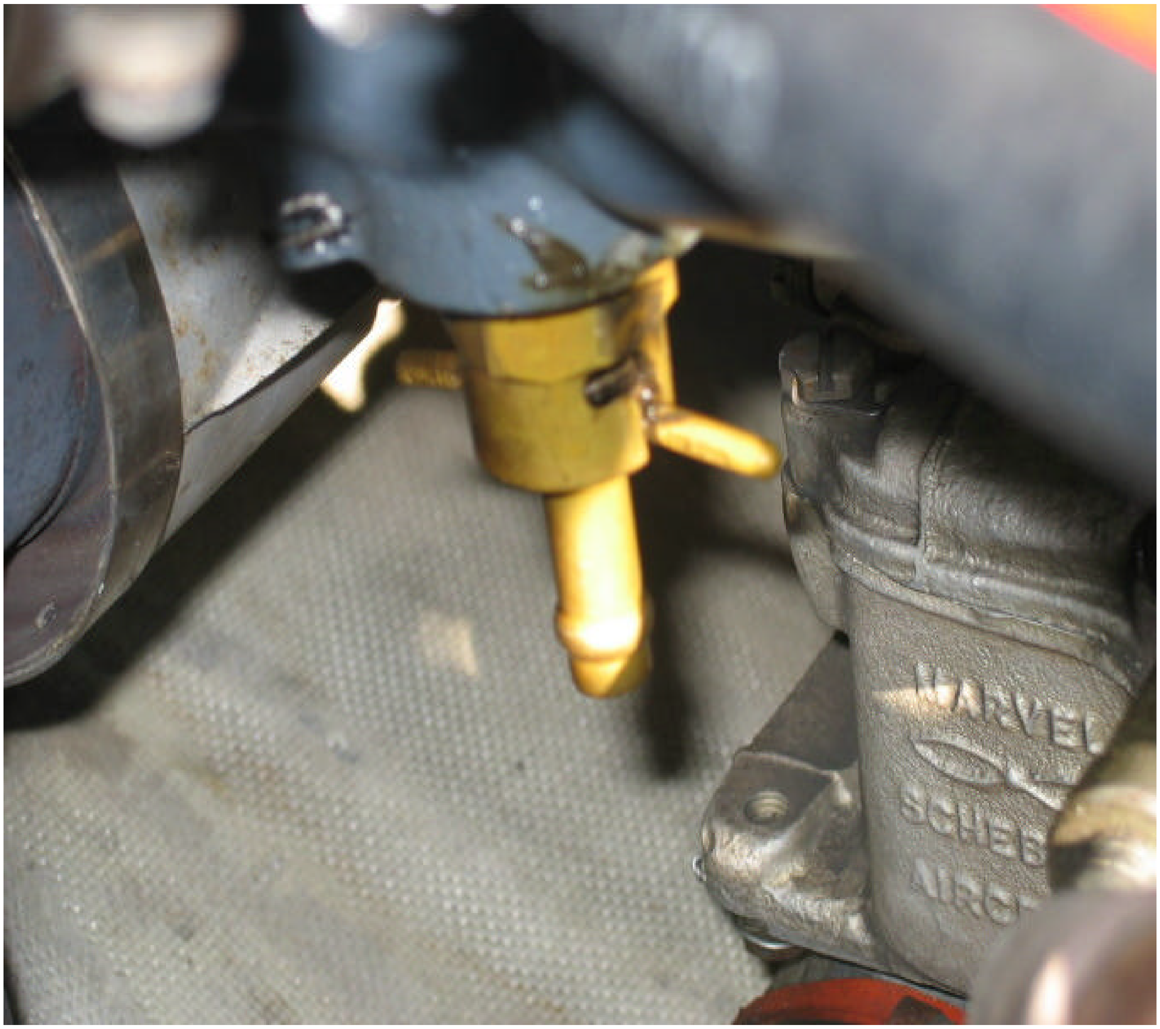
There are a slew of reasons for this lamentable lag. They include; The small market for these engines (some thousands of units a year as compared to many millions of units a year for autos); Disincentives to innovation, such as, fear of lawsuits and the well-known deep distrust of new designs on the part of many pilots, to name a few.

The carbureted Lycomings in our planes are typical of these long outmoded types. Even so, they are among the most successful and reliable of all aircraft piston engines. A better understanding of their strengths and weak-points will help us to get the most out of them while maximizing reliability and avoiding costly and possibly dangerous failures.

A comparison to our modern auto engines highlights the strengths and weaknesses of both types.

It would be hard to find a late-model car that still uses a carburetor to provide fuel mixture to its engine. Fuel injection offers multiple advantages; Quick and reliable starting in all temperature regimes; Much more uniform fuel distribution, leading to smoother and more economical operation; Compatibility with microprocessor control of all aspects of engine operation which makes possible large reductions in polluting engine emissions. These are a few of the advantages we take for granted when we start our new cars.

By comparison, the Marvel-Schebler carburetors found in our planes' Lycoming engines have been serving in light aircraft engines with virtually no change in design or material for over fifty years. They are primitive even by the standards of automotive carburetors of fifteen to twenty years ago. They are totally mechanical - - no failure prone electronics to be found here, thank you, says Joe average pilot. There is no choke control to help with cold starts (automotive carburetors, for at least the last fifty years, had automatic chokes you didn't have to think about at all). Our carburetors feature a weird gizmo called a mixture control, something car drivers haven't had to contend with since the dawn of the motor age almost one hundred years ago. True, some of our older members may recall mixture controls and even manual spark advance on older outboard motors, but they too are dinosaurs - - the motors, not the members.



The rough sand casting of the carburetor body is clearly seen at lower right. Yellow object in center is the crankcase quick-drain for oil changing. Visible to left of the drain is part of the Cabin Heat Muff, which surrounds two of the engine's four exhaust headers.

The magnetos, which provide the all-important spark to ignite the fuel mixture in our Lycomings were adapted from a design common on farm tractors in the World War One era. There's been almost no change in the design in the intervening years although more modern materials have found their way into the newer magnetos. Magnetos are still among the least reliable elements of our aircraft engines. In fact, the FAA is so loathe to trust them that the regulations require us to have two magnetos on board for redundancy. From the standpoint of the FAA it is not IF the magneto will fail, but WHEN. (To be fair, it's not just the magnetos that the FAA doesn't trust, Spark Plugs can be pretty iffy also).   Our   modern car, by comparison, uses microprocessor controlled capacitor discharge ignition with adaptive variable spark timing, to wring every last bit of efficiency from the engine.

What's that about variable spark timing? What dangerous newfangled thinking led to that crazy idea. It's only been in cars for the last seventy years. Way too new and untested to put it in our airplanes. Our planes all have fixed spark advance like the farm tractors of ninety years ago. This means the spark setting is a compromise; too advanced for easy starting and too retarded for efficient running. But hell, why mess with something that works - - sort of.

Unlike almost all modern auto engines, our aircraft engines are air-cooled. There are a number of tradeoffs involved in the decision (made, perhaps irrevocably, many decades ago) to go with air-cooling instead of the more common (in autos) liquid cooling. Right away, we eliminate the weight and complexity of a liquid cooling system - - plumbing, water pump, radiator, and, of course, the weight of the water. We also avoid the need to add antifreeze and the potential for corrosion by the water. In addition we eliminate the hazards of leaks and /or water pump failure, conditions that can lead to rapid and sudden engine failure. Of course, just using an engine in the normal way leads, ultimately, to engine failure, but we hope it will be a very gradual process with lots of warning before the demise.

The advantages of liquid cooling as used in our autos are quite real and giving them up for the greater simplicity of air-cooling results in some real limitations in our aircraft engines. Understanding these unavoidable limitations, we can manage our power plants better, and thus get the most safety, utility and convenience from them.

The first and most consequential of the tradeoffs mentioned above involves heat rejection, -- the process of getting the potentially damaging heat of fuel combustion safely out of the engine and thus keeping the temperatures of the various parts within safe operating limits. Liquid coolants (which are all water-based) offer the immense advantages of being relatively dense and having the capacity to absorb enormous quantities of heat at moderate temperatures. Air, by comparison, is hundreds of times less dense and a relatively poor conductor of heat. Air's capacity to absorb heat is actually quite high, but this factor is quantified as BTUs per pound. It takes more than 112 cubic feet of air, at sea level, to weigh as much as one gallon of water.

What these considerations lead to is the need for the air-cooled engine to devote a good deal of mass to cooling fins on the cylinders. This provides something to take up sudden changes in the engine's heat output with changes in power settings thus smoothing sudden spikes in cylinder operating temperatures. The air-cooled engine also must have a separate oil cooling radiator in order to prevent intolerably high oil temperatures. We see that some of the savings in weight and complexity from eliminating liquid cooling has to be given back to allow engine operating flexibility. An additional major consideration, due to the low density of the air -- a factor that only gets worse as we climb to altitude -- is the need to run higher cylinder head temperatures in order to transfer enough heat to the available air flow.

Increasing the mass of air flowing through the engine could improve cooling but it would, inevitably, require us to sacrifice some greater proportion of the engine's power to pumping the air through the cooling fins (in normal operation a considerable portion, typically several percent, of the engine's power is wasted this way). Further, if we try to increase the mass of air flowing through the cooling fins we also have to increase the size of the fins in order to use the additional air- flow. This, naturally, leads to a further increase in weight. The designers are forced to accept undesirable high operating temperatures as a compromise to keep engine weight at an acceptable level.

The result of these tradeoffs is that our aircraft engines must run a good deal hotter than our car engines do. Our lycomings will normally operate with cylinder head temperatures of 300 to over 400 degrees Fahrenheit while our cars will typically run 200 to 250 degrees. These much higher temperatures (the destructive effects of increased temperatures are not linear, they rise exponentially as temps go up) lead to great stress on engine components, especially the exhaust valves, but the entire cylinder assembly is more highly stressed than the auto equivalent. The engine oil is also more highly stressed in our aircraft engines due to the higher temperatures. This accounts, in part, for the need for more frequent oil changes than in our cars (another important factor here is also heat related – the need to provide larger clearances to allow for the greater expansion of moving parts due to heat results in greater amounts of combustion gasses blowing down into the crankcase to contaminate the oil).

Our aircraft engines also run at much slower speeds (RPMs) than modern auto engines, usually by a factor of two or more. The four cylinder horizontally opposed Lycoming O-360s (5.9 Liter) in our Archers are limited to a maximum of 2700 RPM; By comparison, the four cylinder horizontally opposed 2.5 liter engine in my 2004 Subaru Outback wagon is redlined at 6200 RPM, an enormous difference.

In considering these differences it is important to keep in mind that <u>specific power</u>, the amount of power that any particular engine can produce for a given volume of <u>piston displacement</u> (the basic measure of engine size, usually stated in units of cubic inches or, alternatively, in Liters), increases almost linearly with increases in RPM. So, why would an engine designer limit the <u>specific power</u> output of his engine so severely by setting such a low redline? The answer to this question leads us to the crux of all the differences between aircraft piston engines and any other form of propulsion.

The <u>Propeller</u>. Remember that air has quite low density. Take a look at the propeller of any fairly powerful small boat, say, one that matches our Archer's 180 Horse Power – the propeller will usually measure between 17 and 19 inches in diameter; The props on our Archers measure 76 inches in diameter. In order for any vehicle to accelerate and to continue moving against resistance (drag, for instance) the vehicle must push against something. The more massive the vehicle and the more speed desired the harder must be the push. Water is more than 800 times as dense (heavy for its volume) as air so a rather compact <u>Propeller</u> can shove back a considerable mass of water with each rotation.

So, our aircraft prop must be large in diameter, in fact, the designer would make it a lot larger if he could. Doing so would buy him a lot better takeoff and climb performance at the expense of a few more pounds of aluminum in the propeller. He can't do it! The bigger he makes the prop the slower the engine must turn, and the less power it will be able to produce. The problem here is the speed of the prop tips moving through the air. This speed must be kept well below the speed of sound or else propeller efficiency (the ability to turn Horse Power into thrust) is greatly diminished, and, incidentally, noise levels go ballistic. Anyone who has witnessed a WWII AT6 taking off at full throttle knows what supersonic prop tips sound like and also knows why so many airports set limits on AT6 takeoff power settings.

Now we arrive at the most basic limitation on the design of our engines, the design parameter that guarantees they will remain dinosaurs compared to modern powerplants. Our Archers are limited to a max of 2700 RPM because at that rate of rotation the Propeller blade tips are traveling through the air at Mach 0.8 or, 80% of the speed of sound (at sea level on a standard day) – going to higher altitudes just makes things worse and the faster the plane travels the higher the percentage of the speed of sound (Mach number) becomes. That's why they build in a 20% cushion.

Aircraft designers have tried to get around this RPM limitation by gearing the engine to allow it to run faster than the prop, after all, that's how it's been done in cars since the beginning. This strategy has met with mixed success at best in certified light airplanes. The problems are; Increased weight and complexity; Increased cost; Shorter engine life and lessened reliability and, not least, the requirement for much greater professionalism on the part of the pilot in order to manage the much more finicky geared engine.

Our Archers and Dakota are, by design, simple, fixed-gear, un-pressurized four-seaters intended to be flown easily and economically by low-time pilots without professional qualifications.

Our aircraft have direct-drive low RPM engines, which, since they turn at such low RPMs, must be of large displacement to produce the needed power output for reasonably good performance. As an example, the Archer's Lycoming engine has a displacement of 360 cubic inches for an output of 180 Horse Power; My Outback, by comparison, displaces 152 cubic inches for an output of 165 Horse Power. The Outback's engine achieves more than twice the specific power of the Lycoming. Amazingly, the Lycoming, while heavier than the Subaru engine, is nothing like twice as heavy. Lycoming, through years of refinement of the basic old design, has managed to pare the weight per cubic inch to a remarkably low figure. There is a penalty for shaving weight to the minimum. Our aircraft engines are quite "tender', they must be babied to get long and reliable service from them.

What follows will be a set of guidelines, suggestions and tips for managing our engines so as to get the best from them in the safest manner.

We'll look at a typical flight; Going through all of the steps in order, beginning with:

a. **Flight Planning**

b. **Pre-flight Inspection**

c. **Starting**

d. **Pre-takeoff and Runup**

e. **Takeoff and Climb**

f. **Cruise**

g. **Descent and Pattern**

h. **Taxi back and Shutdown**

a. Flight Planning

Factors in our flight planning that are Engine-Related include:

1. **Time of year and Weather Conditions**.

2. **Distance and Duration of flight (Fuel Consumption).**

3. **IFR or VFR (Fuel Reserves).**

4. **Takeoff Runway Length/Density Altitude (Need for Max Performance).**

5. **Availability of Appropriate Fuel at points along Route**.

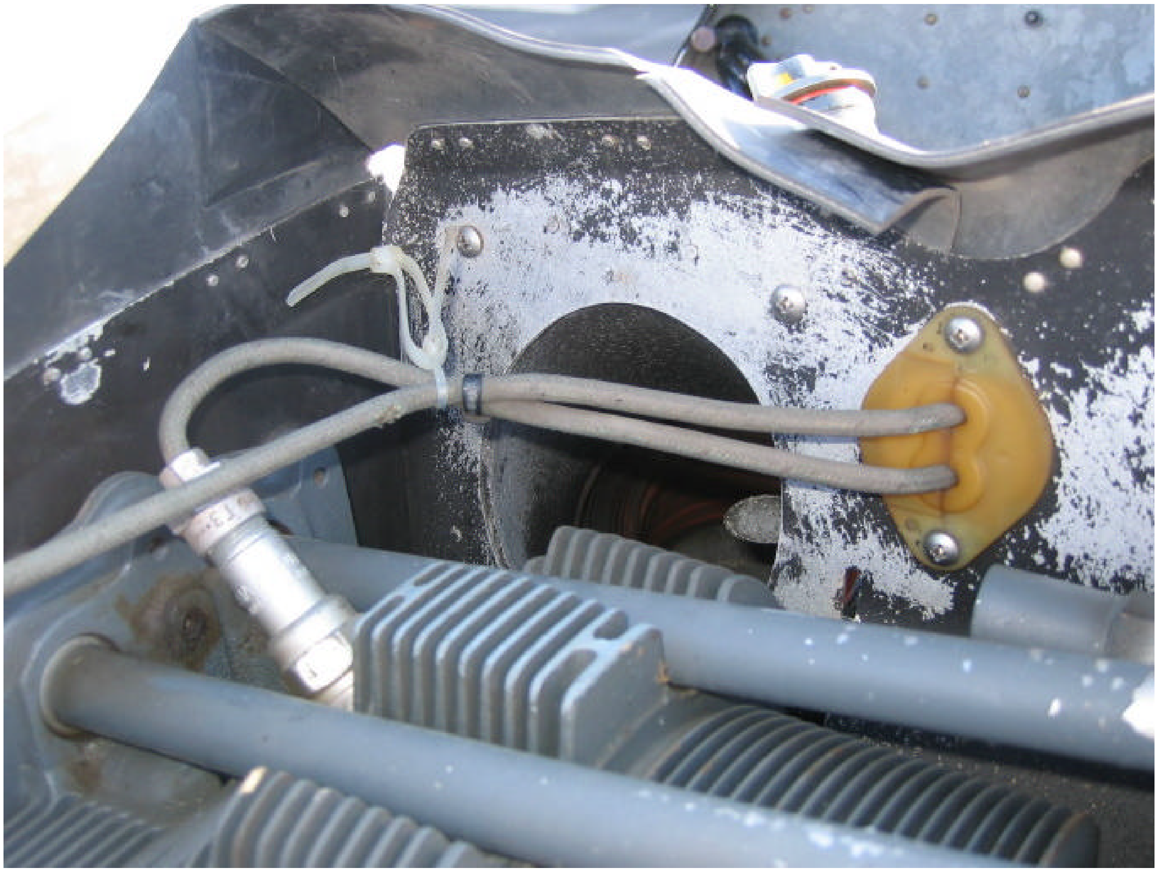
6. **Special Engine Requirements (During break-in, for instance, Economy Cruise may not be possible).**

1. Time of Year and Weather Conditions: We are all conditioned from our earliest pilot training to be aware of weather factors when planning a flight. It's important to include engine considerations as we make our plans. Winter brings the need for pre-heat for starting when temps are likely to dip below about +20 degrees Fahrenheit. It's our responsibility to make sure adequate pre-heat is used. This may mean calling the airport the day before to be sure that the Electric Pre-heat is plugged in for the night. If you're planning to overnight at some other field where an electric outlet may not be available then you'll have to call ahead to ascertain that some form of pre-heat can be provided. Of course, we all keep in mind that the club will pay for a pre-heat, and or, pay half the cost of putting the plane in a heated hangar when no other means of ensuring a warm start is available. This is not an example of altruism on the club's part, it's recognition of necessity. Paying for pre-heat is a whole lot cheaper than paying for a new engine…it's that simple.

It's important to keep in mind that if you're planning an early departure from some field where you'll be dependent on a portable pre-heater you'll need to get there quite a bit early to allow for the inevitable delays in getting someone to break out the heater and then the wait of at least 15-20 minutes for the engine to warm up. Might as well plan on having another cup of coffee. And by the way, don't be swayed by the lineperson who, after perhaps 5 minutes of pre-heat, puts her hand on the cowling and says to you "There you are, all warmed up." It's going to take at least 15 to 20 minutes to warm several quarts of oil deep in the engine's innards.

If you don't get that oil warm and circulating freely, you will do damage to the engine when you start it. At very low temps the oil is the consistency of peanut butter and the oil pump cannot move it through the engine to
lubricate wear-prone parts.

Another vital seasonal consideration is changing the Oil Cooler Block-off Plate found in our Archers; This is not "The Mechanic's Problem." It is yours as the pilot. The FARs make it clear that you must assure that the aircraft is "airworthy," a legal term, before any flight. The oil cooler block off plate is a small and deceptively light piece of sheet metal located beneath the upper cowling just to the rear of the engine cylinder heads on the passenger side. The Aircraft Flight Manual states that it must be in place when ambient temperatures are below 50 degrees Fahrenheit and it must be removed when temps are above 50 degrees. This smells like an afterthought fix for a design problem. The engine's oil cooling isn't well enough regulated without this kluge, and we're stuck with juggling the ball.



Right (passenger side) rear cylinder and its upper spark plug with high- tension wires are visible just ahead of the large round hole in the Rear Baffle. This is where the <u>Oil Cooler Block-Off</u> Plate is to be attached using the two small Phillips Screws on the Baffle above the large round hole. A severe wear point on the Air Dam is visible directly ahead and left of the Oil Filler Cap. A hole farther left is from careless installation.

Don't think this is a simple twice a year deal. Just consider what you must do if you decide to take a trip South in winter as I have done several times over the years. Somewhere over Virginia or the Carolinas or Georgia as the case may be you're going to see the temps advancing into the 50s and 60s, after all, this is probably a large part of your motive for the trip. Now you're going to have to land and remove the bleeping thing. You'd best have a stubby No2 Phillips screwdriver and a pair of pliers in your kit…Mechanics don't like to lend out their tools. Oh, by the way, make sure the plate stays in the plane. You'll need it for the return trip.

Failing to heed the Manual on changing the Block Off Plate <u>can do damage</u>. Leave it on in hot weather and you'll overheat the engine oil; this can cause the engine to overheat with possible catastrophic effects, although, you'll more likely do hidden damage that won't show up right away. Leave it off in cold weather and there'll be a whole slew of consequences. Depending on which ones predominate the damage could be slow and cumulative or you could face something worse.

2. Distance and Duration of Flight: A book could be written on the subject of fuel management, in fact, several have been written. I'll try to keep it brief.

The basic tradeoff is Performance vs. Range. Our engines can provide one or the other or a middling compromise but you do have to know how to manage the engine to get the most of what you want out of it.

We've all been taught that normal cruise is 75% power. Some aircraft manuals list even higher percentages of power. Our Dakota's manual lists 85% as an allowable cruise setting. This is all the work of marketing departments. The tenet is that "speed sells" and the highest possible power settings make it possible to claim "astounding speeds." Often lost in the hype is the substantial decrement in fuel economy that is the price you'll have to pay if you fall under the spell of the advertising guys. There may be a proper occasion for the highest cruise power settings. But I find it hard to think of an important one.

The differences in fuel consumption at the highest vs. the lowest published power settings can be truly eye opening. Our Archer IIs' Operating Handbook lists fuel consumption figures from 10.5 GPH at 75% best power mixture down to 6.3 GPH at 55% best economy mixture. (I have been able many times to verify these book figures in flight. Flown as directed by the manual these figures can be relied on). The difference in speed between the two settings is 19 Knots. To put it in the clearest terms; you'll give up a bit less than 15% in speed and burn 40% less fuel per hour. Over a distance of 250 Nautical miles (288 statute miles) you'd have arrived 20 minutes sooner, but to save that bit of time you'd have burned 4.1 additional Gallons of close to $3.00 per Gal avgas.

I don't know about you folks, but I'm always looking for ways to log more hours and since we pay for Tach time, and log Hobbs the slower trip will actually cost less, while adding more hours to my logbook. (Tach "Time" is actually a measure of how many revolutions the engine turned during the flight. Lower power means lower RPM thus fewer total revolutions per trip, hence less Tach Time).

On longer trips you can actually arrive at your destination sooner at the lower power settings if the extension in range allows you to cut out a fuel stop. As an illustration:
In the examples just given the absolute (no reserve) ranges are:
At the higher power setting. 565 Nautical miles (650 Statute miles).
At the lower power setting. 803 Nautical miles (923 Statute miles).
A difference of…………… 238 Nautical miles (273 statute miles).

3. IFR or VFR: Another important motive for flying conservative power settings is the ability to file IFR when the distances involved are fairly long, especially if you are hoping to get past a rather widespread area of low ceilings and still need to arrive with ample reserves to make an alternate that itself may be at a considerable distance.

I once made a flight from Danbury CT to Keene NH on a day when the nearest legal alternate was Baltimore MD. In order to launch and remain legal I had to be confident that I could miss the approach at Keene and then fly to Baltimore, make the approach and land with a comfortable fuel reserve. As is so often the case conditions lifted a bit and I was able to make the ILS at Keene without a problem. But, Hey, you never know.

4. Takeoff Runway length/Density Altitude: Hot and high takeoffs are a staple of the accident reports and we need to be aware of power management issues that bear crucially on this type of operation.

We Eastern flyers tend to think of high density altitude as a problem encountered only when west of the Mississippi. In fact it can bite us anywhere we fly. Quite early in my flying career it almost got me when trying to take off in a heavily loaded (and rather tired) rented C-150 from a near sea level 2000 foot runway one very hot July day. I had to steer the plane between tall pine trees on our climbout. I scared myself and an unsuspecting non-pilot passenger that day. The experience sent me scurrying to a flight instructor for brush-up lessons on short field and high-density altitude operation.

The Aircraft Manual says very little on leaning for Best Takeoff Power at high-density altitudes, and it states only the bare minimum information on leaning for fuel economy. We'll discuss these topics in some detail in **Chapter Two.**

b. Pre-flight Inspection

Subjects in this category include:

1. Getting At the Engine (The cowling – to remove or not to remove)

2. The Problem of Aging Aircraft

3. What to Look For

4. The Engine as a Complete Powerplant (Firewall forward)

5. Understanding What We See (knowing Our Systems)

6. Checking and Adding Oil

7. Putting it All Together

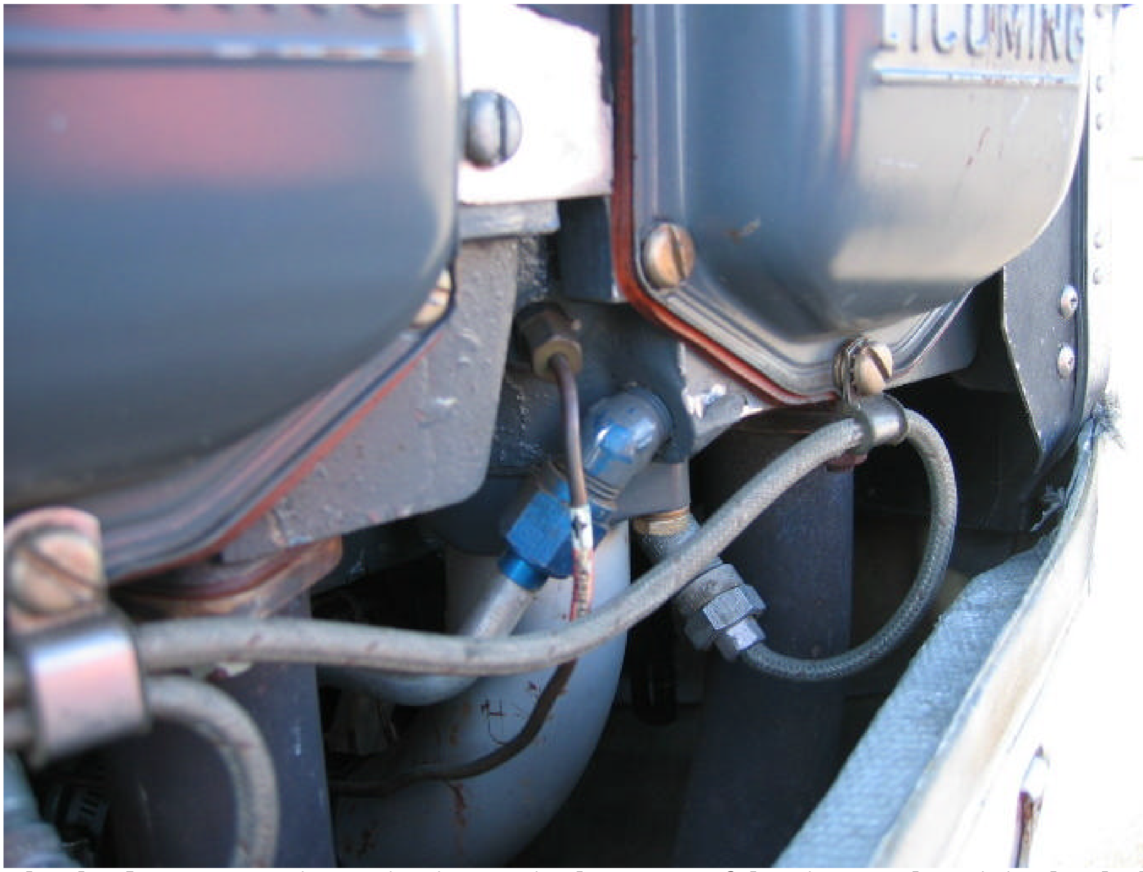
1. Getting At the Engine: Those of us who trained on Warriors are probably a bit shocked on first discovering that the cowlings on Archers and Dakotas have no hinges, just a little door you pop open for getting at the dipstick. How are you supposed to preflight an engine you can't see? Of course, the upper cowling is removable but taking it off prior to your flight may seem a bit intimidating the first time you do it and taking it off before every flight seems daunting. There are pitfalls for the newbie but old Cherokee hands may also run into problems in handling the cowling. The thing is kind of large, a bit on the heavy side for easy handling, Tricky to take off and even trickier to get back on properly. On a windy day this is definitely not a one-man job. What's more, the cowling is sort of fragile and failing to re-install it properly can have serious, even tragic consequences.

Correct fastening of Cowl Latch—the upper end of the pivoting part of the latch mechanism must engage under the downward-bent metal lip on the lower cowling.

Incorrect: the pivoting part of the latch mechanism has failed to engage the lip on the lower cowling.

So, what to do? Maybe we should just leave it on all the time and make the best of it by peering in at what little we can see from the outside. A recent experience of one of our members advises against this course. He decided to pull the upper cowling for a thorough pre-flight and, while carefully examining the engine, he discovered that a primer line was broken in a location that would result in it spaying raw avgas on the engine with each stoke of the primer. In this case the risks from removing the cowling for a more thorough pre-flight were definitely outweighed by the risks of leaving the cowling on. Of course, the airplane was NO-FLY and it's a damned good thing he found out.

On another recent occasion Member John Scarfi and I were demonstrating preflighting to a group of members. We took the cowling off one of the Archers and John discovered that a the high voltage ignition wire supplying an upper spark plug was not properly secured against vibration and had, consequently, been chafing against a metal baffle. The wire's insulation was partly worn away. It would soon have failed, leading to an inability to obtain full power. If this condition were picked up during a mag check there'd be no danger, just the disappointment and inconvenience of a cancelled flight. But suppose the malfunction first manifests itself on a critical takeoff? Perhaps from a short field? The consequences could be serious.



The slender copper Primer Line is seen in the center of the picture where it is plumbed into the intake port of the right (passenger)side front cylinder. The bright blue fitting connects an oil return line to that cylinder's rocker box. A lower spark plug and its high-tension wire are visible at lower right. The dark column behind them is that cylinder's exhaust header.

Still, it is inconvenient and difficult and, potentially, damaging to the aircraft to be constantly taking the cowling on and off. The compromise I've worked out with myself is to take it off when doing so is reasonably straightforward – Daylight hours; Help available if it's windy; Not in the pouring rain, or when an immediate departure is truly a necessity. When I can I'll take the cowling off for a more thorough pre-flight. Of course, if you're unsure of the proper procedure you'd best ask a mechanic or one of the more experienced members for a brief tutorial. When in doubt always look for help.

2. The Engine as a Complete <u>Powerplant</u>: Modern practice is to view the engine as part of the <u>Powerplant,</u> consisting of everything ahead of the firewall that is involved in making, using and controlling power. A very few parts of the <u>Powerplant</u> can be accessed without removing the cowling. These include the propeller, fuel drains, oil filler/dipstick, alternator-drive belt and, of course, the cowling itself (we are interested here in the cowling's integrity, proper fastening and etc).

***Most of the Powerplant may be viewed once the upper cowling is removed. The lower cowling can be removed with a few tools and a bit of perseverance, but this access is mainly of interest to the mechanic when he needs to get at the items on the underside of the engine for maintenance and repair*.**

3. The Problem of Aging Aircraft: We are flying aging aircraft and so, it behooves us to take extra precautions to try to catch the glitches, malfunctions and breakdowns that can be expected to increase in frequency as our aircraft continue to age.

The broken primer line mentioned above is a case in point of the problems of aging aircraft components. A chief mechanic once told me, after an earlier and much scarier incident of a broken primer line (it dumped a substantial quantity of raw fuel into the aircraft cabin in flight), that these components, which are made of soft copper tubing, ought to be replaced at least every ten years or so.

The problem is that copper is a member of a group of metals that exhibit a property known in the metalworking industry as work hardening. This is a process that is caused By any sort of working of the metal, such as, bending, squeezing, cutting, hammering, etc. In the case of the primer tubing, vibration, of which there is a great deal with the engine running, causes the tubing to flex ever so slightly many millions of times during the life of the plane. This leads to embrittlement of the metal (work hardening) and eventually the tube cracks at some particularly vulnerable point. There is no requirement from either the FAA or from Piper that these lines be replaced periodically, or ever for that matter.

4. What to Look For: A famed woman aviator (I believe it may have been Jacquelyn Cochran) wrote that pre-flighting an aircraft engine is very simple: Just make sure there is nothing loose, nothing hanging and nothing dripping. Sounds easy, however, as always, the devil is in the details. And we still need to know what it is that we are looking at.

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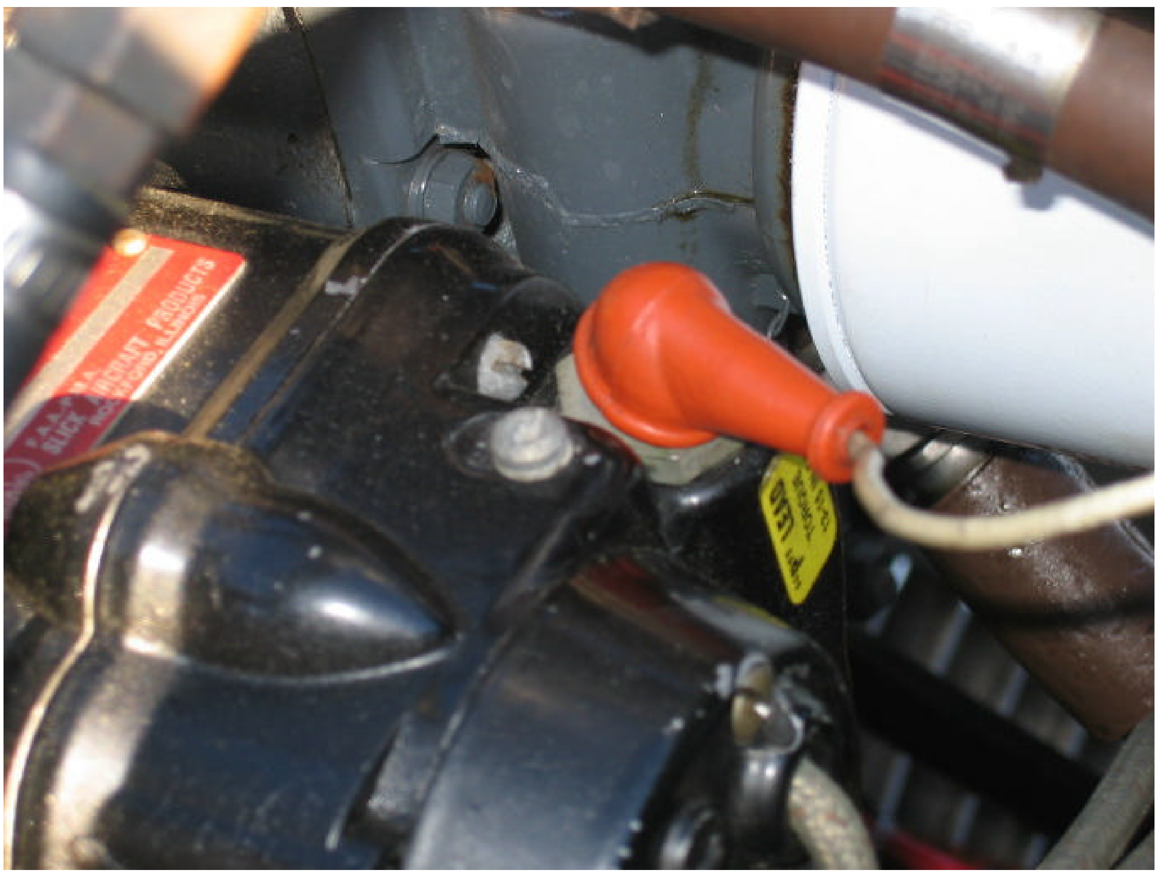
How many of us know what a P-lead is, never mind ascertaining that it isn't broken. Yet, over the years there have been numerous accidents and fatalities due to broken or disconnected P-leads. Now that you've gotten real interested, I might as well tell you what a P-lead is. It's a very slender length of wire that runs from a magneto to the ignition switch. Its function is to short out the magneto, so as to turn off the ignition.



The shiny black object in the left foreground is the left (pilot's side) magneto. The 'P'lead attachment point is clearly labeled in yellow. The 'P'lead itself is the slender white wire snaking away from the red terminal cap. Large white object to upper right is the oil filter.

A magneto is always on, even when the Master Switch is shut off. So, the only way to make sure the engine will not fire is to short-circuit the magneto. If the P-lead breaks or somehow becomes disconnected, then the ignition for that magneto is ON even though you have shut down the ignition switch and taken out the key. This explains why we are taught to always treat the engine as if the ignition is on. You see, even if the P-lead is intact the ignition switch could be defective and this would mean that -- you guessed it -- the ignition is ON. This, by the way, is why it's never a good idea to let your passengers pose for pictures while leaning a hand on the prop. Even slight pressure on the prop can cause it to move just enough to cause a magneto to click over and send a spark to a cylinder that might have fuel mixture in it. The tragic outcome, documented many times, is a dead or severely injured person.

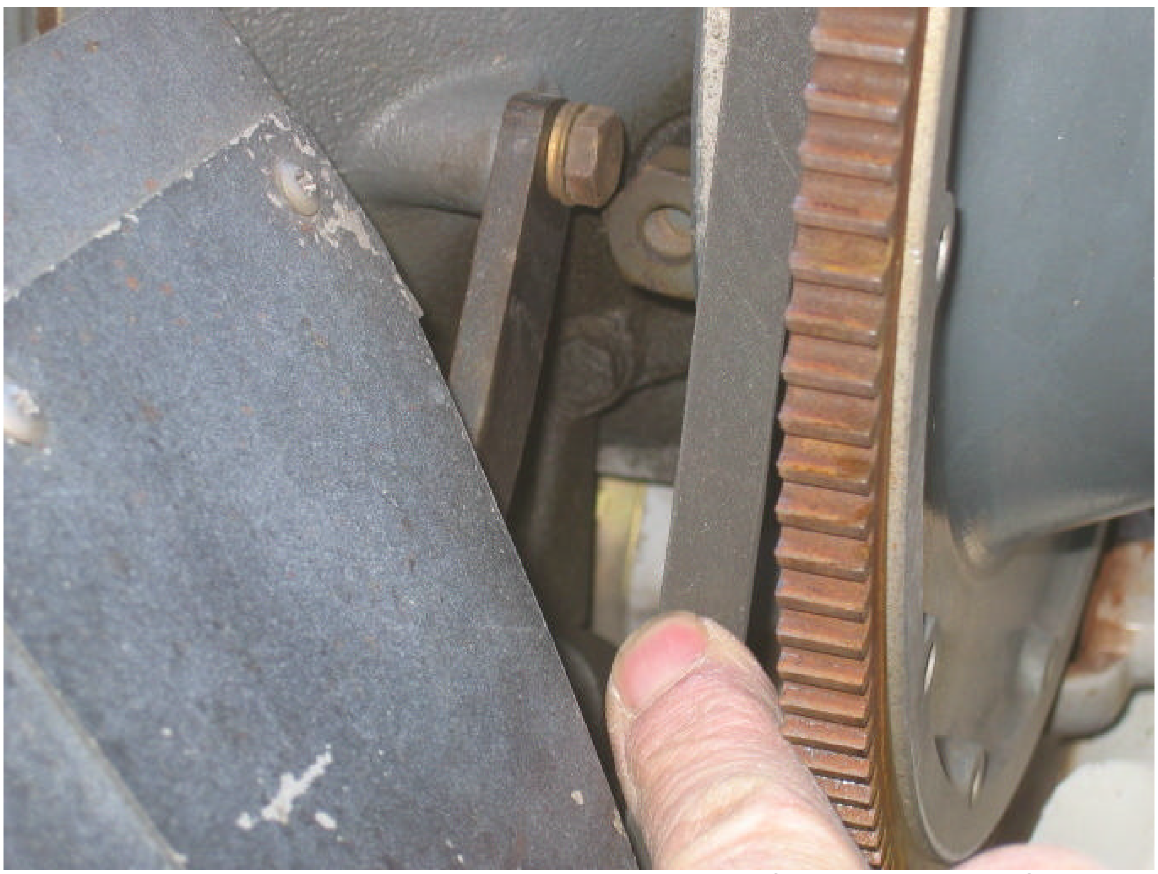
5. Understanding What We See: Perhaps the first things we see on removing the cowling are the system of Baffles arranged on top of the engine. These are too often ignored, for they are very important to the life and health of the engine. The function of the Baffles is to force the cooling airflow coming in through the inlets at the front of the cowling to blow down through the engine's cylinder cooling fins.

In this view from behind the engine on the pilot's side, the rubber air dams on the baffles are clearly seen at the upper left.

The Baffles are composed of sheet-metal partitions that sprout rubberized fabric extensions on their upper edges. The rubbery parts are barriers (air dams) that are designed to press against the inner surface of the cowling to prevent air from leaking past the metal Baffles. These rubber strips tend to deteriorate in service because they operate in a harsh environment. They are subject to extremes of heat and vibration from their proximity to the engine. At all times when the engine is running it shakes,rattles and rolls and the rubber air dams must constantly flex and rub against the inner surface of the cowling.

When the Baffles begin to fail they first loose their stiffness and are no longer able to provide a good seal of the gaps under the cowling. As they continue to deteriorate they develop cracks and torn areas. The loss of effective sealing around the Baffles results in poor engine cooling which can very quickly lead to major engine problems from overheating.

Inspecting the Baffles for wear and tear is a straightforward operation requiring judgment and careful attention, but no special skills. Normally, all of the rubber air dams curl inward toward the engine. Any of them that appear to curl away from the engine may be assumed to have lost effectiveness and need attention from a mechanic. Obviously, torn, cracked or missing items also need immediate attention from a mechanic.

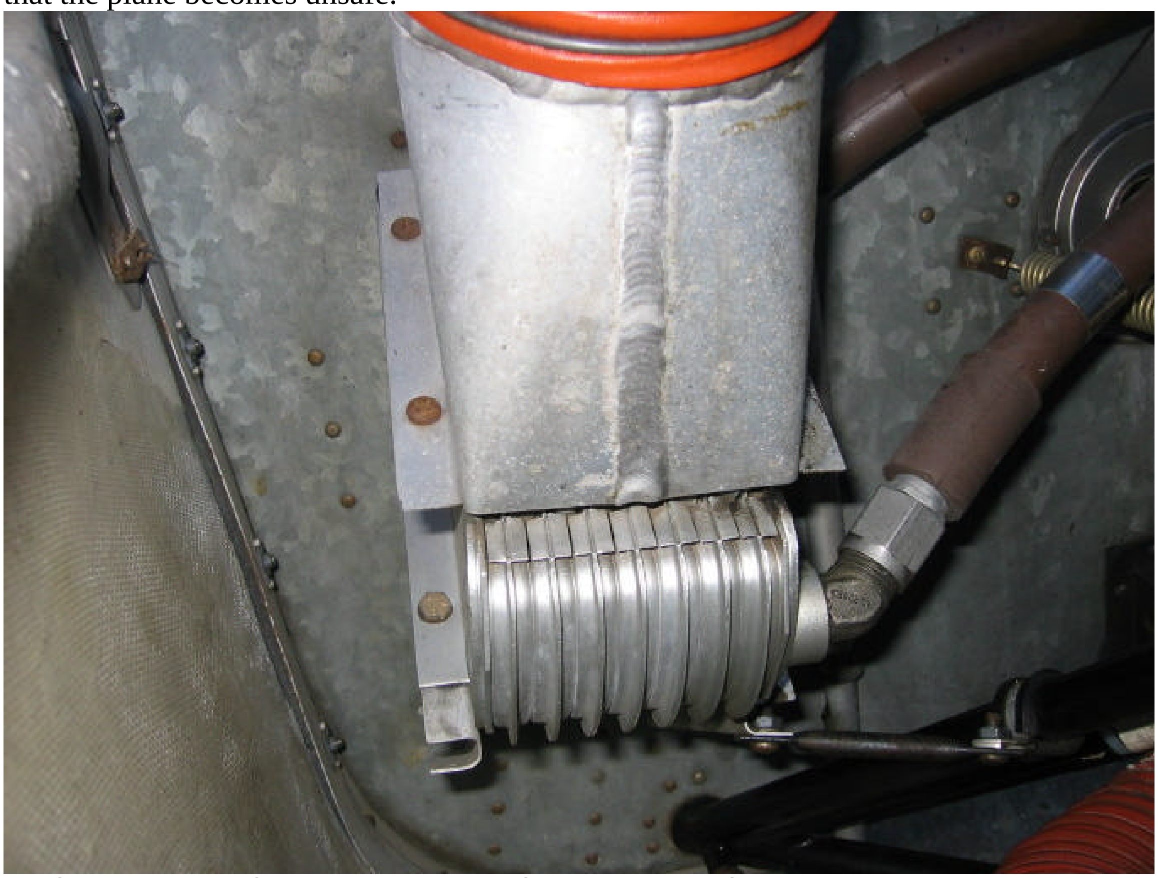


The Alternator Drive Belt should yield only about one half-inch to moderate finger pressure. This is one of the few items that can be assessed without removing the cowling. It is reached through the passenger side cooling air inlet . Part of the alternator bracket is visible parallel and to the left of the belt.

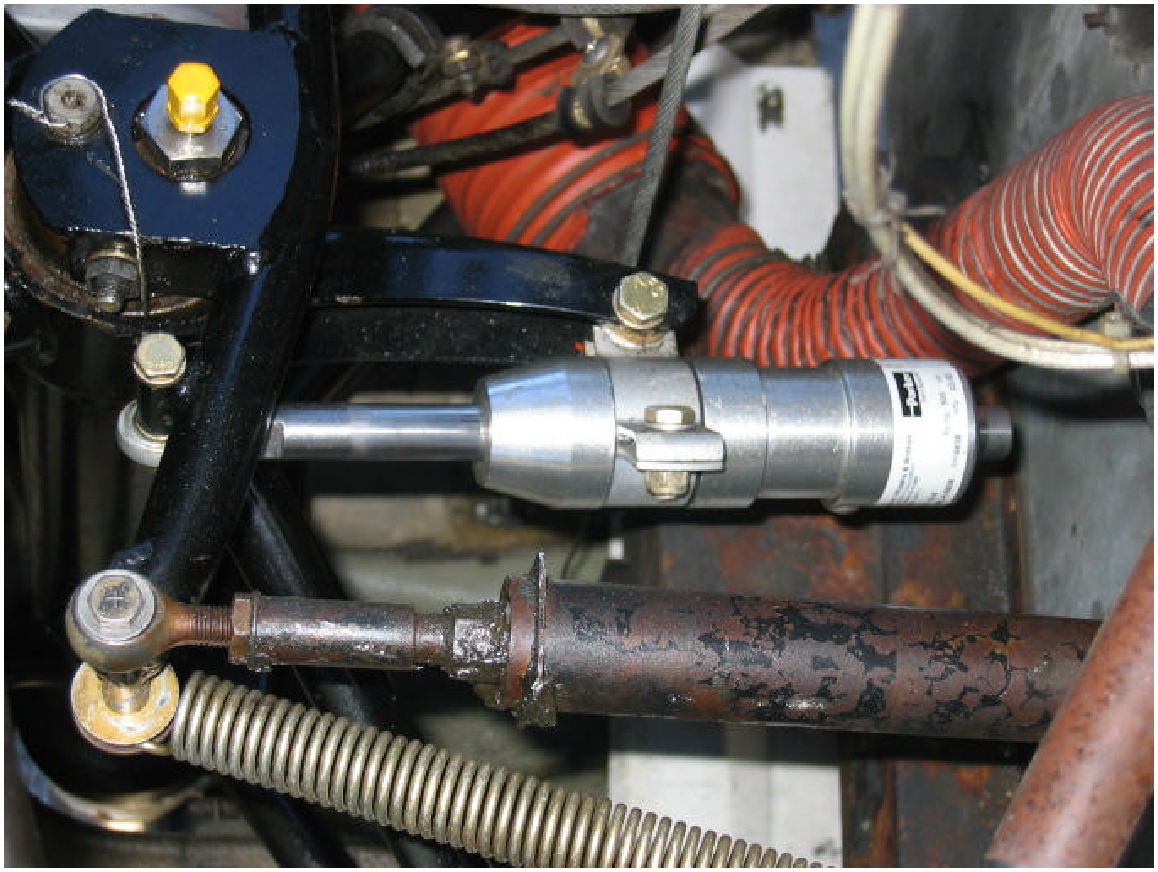
Nothing Loose, Nothing Hanging Nothing Dripping: These are good guidelines. As we look further in the engine compartment, we can add, Nothing Broken. Spark plug wires and primer lines have already been mentioned. We can also look closely at accessories.

The alternator and starter are at the front of the engine. The first thing to check is the condition of the alternator belt. It should not show signs of advanced wear, such as, cracking of the rubber or fraying. The belt also should have good tension – moderate finger pressure should deflect it no more than half an inch. Cherokees have long had a problem with cracking alternator-mounting brackets. This is a more difficult item to see without further disassembly, but if the bracket is cracked there will most likely be noticeable looseness in the belt.

While looking at the front of the engine we have a chance to examine part of the propeller assembly that we can't see from an external check. The spinner and its backing plate need to be examined for cracks. This failure is seen surprisingly often and can lead to loss of part of the assembly. The resulting unbalance can create such severe vibration that the plane becomes unsafe.



Shifting attention farther to the back of the engine we find the oil cooler. It is mounted on the firewall. The red ducting, just visible at top connects to its cooling air inlet, located on the passenger side rear <u>Baffle</u>, the spot where the previously mentioned block off plate attaches.



Looking down through the accessory section, the shiny silver object in center is the shimmy damper. The greasy tube below is the left rudder push rod assembly. The rudder return spring is attached to it. The yellow cap covers the fill valve of the nose wheel strut. Red flex duct at upper right supplies hot air to the pilot's side defroster vent.

Rearward of the rear Baffles is the accessory section. This is a crowded and potentially confusing area full of hoses, tubes and wires, including the previously mentioned P-leads. The magnetos are located here, bolted directly onto
the rearmost part of the engine -- known as the Accessory Case. The vacuum pump also bolts onto the Accessory case. Looking down we can also see the nose-wheel assembly and the steering damper, a part that has frequently been troublesome for us.

We can't hope to troubleshoot much of this stuff, it's too complicated, but the admonition to look for things that are "loose, hanging, dripping or broken" applies here with especial importance.

6. Checking and Adding Oil: We use Shell Multi-Weight oil in all three planes except during break-in after an engine rebuild. There is no need to be concerned about mixing a different brand, if, when away you can't obtain our brand. All certified aviation grade motor oils are compatible.

There is a noticeable difference in the oil filler access between the Archers and the Dakota. The Archer's access door is on the passenger side of the cowling while the Dakota's is on the opposite side. But the differences go deeper than this. The Archers use a screw in style filler cap-cum-dipstick which is very easily over-tightened and devilishly hard to unscrew after someone has put too much muscle on it. Please try not to make it too tight. Use only very light force on it. (Two fingers very softly with no heavy wrist action.) It will not come undone in flight, honestly.

The Dakota uses a quite different method of fastening the oil cap. I like to think that the designers heard the pleas of all the pilots with sore fingers from unscrewing their oil caps when they made the change. The cap on the Dakota is a joy to use. It simply pops in and out with so little fuss that at first I thought something was wrong with it.

The oil levels in these planes have come in for a good deal of discussion. The main questions being around what level is safe and appropriate? The Archers' dipsticks are marked up to a maximum level of 8 quarts and the Dakota's goes up to 12 quarts. The perennial question is "Shouldn't the level be brought up to max before a flight?" Answer: **"NO, not at all."**

It has been found over years of experience with these engines that more than 6 quarts in the Archer or 9 quarts in the Dakota is overfilling. In flight the excess oil above the 6 or 9 quart level quickly gets blown out the crankcase vent adding an expensive new layer of grime on the undersides of the planes. Overfilling does nothing to increase safety.

The archer manual states that it is safe to operate the engine with as little as 2 quarts of oil in the crankcase. The Dakota's engine can also run safely with a surprisingly small amount of oil. Our planes consume oil very sparingly -- 5 or 6 hours per quart – so the specter of running the crankcase dry on a long flight may be completely dismissed.

7. Putting it All Together: This entails a lot more than just getting the cowling back on properly. By now we should have a sense of the powerplant as a complex system comprising a number of sub-systems. There are the: Fuel System; Lubrication System; Induction System; Electrical System; Vacuum System and others. We need a good working knowledge of all of the planes Systems to be proficient pilots. For our Pre-Flight Inspection of the Powerplant we need only consider what we can learn by eyeballing these Systems to reach an informed decision on the engine's suitability for the next flight. Of course, a thorough pre-flight will involve looking at the whole airplane as well as the powerplant, but that is beyond the scope of this discussion.

c. Starting

Subjects in this section include:

1. The Engine Controls (Throttle, Mixture Prop, Heat, Fuel Selector)

2. The switches (Master, Ignition, Fuel Pump)

3. The Primer – Hot vs. Cold Starts

4. The engine instruments

1. The Engine Controls: The first thing to do with them after getting comfortably settled and belted in is to exercise each control through its full range to assure smooth and appropriate travel. Try not to work the Throttle more than once as each time you shove the throttle open it causes the carburetor's Accelerating Pump to squirt a jolt of raw gas into the plenum chamber attached to the bottom of the carburetor. If this accumulates from successive strokes of the Throttle it will create a very serious fire hazard. A backfire while cranking the engine for starting can ignite the puddle of fuel causing an engine compartment fire that you may not even become aware of until it's too late to put it out without major damage to the aircraft. Many planes have been lost this way.

Even though the Archer's manual advises using the Throttle's Accelerating Pump to prime the engine for starting, this is a definite No-No as explained above. The only reason I can imagine for Piper putting such bad advice in the airplane's Operating Manual is that the Primer is an extra cost item and perhaps Piper felt obliged to provide a way of starting the engine without a Primer.

I've flown with a number of our members and seen more than a few use the Throttle for priming. I refrained from saying anything that might seem critical on those occasions and I want to be clear that I'm not criticizing now. Many flight instructors teach this faulty method and we pilots, when we were students, pretty much accepted the instructor's behavior as The Way it's Supposed to Be. After all, that godlike fellow could control the plane and get us down safely, whereas, when we tried it, at least in the beginning, the plane was all over the place and we couldn't get it back on the runway to save our skins.

The Experts, and this includes the Archer's Manual, all recommend that if you get an engine fire from using the Throttle to prime the engine you should continue cranking the starter to "suck the flames into the carburetor." Sounds just dandy to me; First you ignore a perfectly good Primer and use the Throttle instead and then you hope to put out the resulting fire by "sucking it into the engine." This, of course, is the moment to discover that the battery is low and can barely crank the engine at all. I hope I've made my point.

One often-overlooked step to take with the engine controls is to immediately set the Fuel Selector on the fullest tank. Regardless of what the Manual may have to say about when to do it, this is best done now. The worst possible move would be to belatedly realize you hadn't done it in the pre-takeoff sequence and then reach down to correct the mistake just before takeoff. There have been many serious accidents that were precipitated by this move.

The problem is that you may not get fuel flow to the engine when you think you've got it. The fuel selector may hang up between tanks (has happened often): You may select a tank with little or no fuel (it happens), or there could be a blockage in that tank's lines. If any of these problems crop up and you've made the tank selection as a first move then you'll find out during taxi and run-up. OK, you've got a problem, but, big BUT – YOU ARE ON THE GROUND. There's usually enough fuel in the carburetor's float chamber to get you from the run-up area to the runway threshold and maybe 50 or 100 feet off the ground before it suddenly gets real quiet in the airplane. This little scenario has happened all too often and frequently with fatal results.

2. The switches: Contrary to what most of us have been taught and even contrary to what The Manual says; the first switch to touch for engine starting is not the Master Switch. The first switch we touch is the Avionics Master to be absolutely sure it is in the **off** (down) position. This is done so that we don't fry about $25K of electronics. When we start and, also, when we shut down the engine there are potentially destructive "voltage spikes" in the plane's electrical circuits. So, we also turn off the Avionics Master before shutting down the engine. The reason this is not mentioned in the Manual is that the planes didn't originally come with Avionics Masters. These are aftermarket items that we had installed some years ago.

You may well ask why you don't fry the electronics in your car when you start it or shut it down. The reason is that there are automatic protection circuits in your car that shut off the electronics as you turn the key to start or stop the engine. Ever notice how the radio won't play for a second or so after you restart the car if it has stalled. Our planes operate on a different concept; we don't have anything on board that is going to shut down any important system unless we tell it to.

The next switch to use is still not the Master switch, It's the Electric Fuel Pump Switch. There's a very good reason to do this before turning on the Master. If you follow the Piper checklists they may seem to be telling you to check the operation of the Electric Fuel Pump after you've started the engine! Well, how are you going to get a good reading on the Electric Pump's operation when the Engine-Driven Fuel Pump is providing full pressure (about 4 PSI) to the system?

So, we flip on the Electric Fuel Pump Switch first, then, when we finally do turn on the Master Switch we'll hear and see that the Electric Pump is running. The sound you'll hear is a sort of rapid-fire hammering from up front on the firewall. That's the Electric Fuel Pump kicking in. The sound will taper off after a second or two as fuel pressure comes up to its regulated value. You'll see it on the Fuel Pressure Gauge, Which is the first panel instrument to check in the starting procedure.

The two instruments we look at immediately after the engine starts are, of course, the Oil Pressure Gauge and the Tachometer. If Oil Pressure doesn't come up, within a dozen seconds, to a value in the Green on the gauge we must shut the engine down immediately to avoid doing about $15K of damage to the engine. While making sure that we have adequate Oil Pressure our eyes ought to move to the Tachometer to verify that we have the engine running at the appropriate very low RPM (just above idle, to minimize engine wear during the critical first few seconds of operation when the engine is receiving very little in the way of lubrication).

When, finally, we do turn on the Master Switch there is, as with just about everything in our planes, a right and a wrong way to do it. Our Pipers employ a Split Master Switch, something that may be new to some of our members. This feature requires a bit of understanding to make full use of it. The switch is split vertically into Left and Right Sections. The Left Section, called the Battery Master controls the Battery Relay, hidden away in the bowels of the plane. Flipping on the Battery Master causes the Battery Relay to connect the battery to the plane's electrical buss, thus powering up the plane's electrical system. The Right Section of the Master Switch is called the Alternator Master and it controls the Alternator Relay whose function is to connect the Alternator (a form of electricity generator) to the Charging Circuit so that we don't run down the battery with the plane's electrical demands.

The Split Master Switch provides a number of advantages. Firstly, it allows us to protect the sensitive electronics of the Charging Circuit's voltage regulator from the previously mentioned voltage spikes associated with use of the starter circuit. So, for this reason, we always use only the Battery Master (Left Half of the switch) for engine starting. Another advantage of the split system is that it allows us to better assess the health of the Charging Circuit when we do bring it online.

We watch the Ammeter or Loadmeter for indication of substantial output and a small but definite rise in voltage with the Alternator online. You may have to increase the engine's RPM slightly to see this voltage rise. If, however, you have to increase the RPM substantially, say an additional thousand RPM, to see good charging then the system is not performing satisfactorily and requires urgent attention.

An all-important function of the Split Master Switch comes into play when we experience a failure of the Charging System. We are better able to conserve whatever battery capacity remains for the necessary Com and Nav functions by putting the Alternator offline, (when the charging system fails the Alternator can begin to act like an electric motor and put a heavy drain on the battery). So, in such an emergency we shut down the Charging Circuit by flipping the Right half of the Master Switch, the Alternator Master to the **off** (down) position.

Another use of the Alternator Master, when the Charging System fails is to try to get it up and running again by re-cycling the alternator. To try this, first turn off the Alternator Master and let the system rest and cool down for a couple of minutes while you turn off as much unessential load as possible. Lights, cabin vent fan, even the transponder are not essential to the completion of the flight. Now you bring the Alternator back online and see if you get an indication of normal charging. This often doesn't work but it may be worth a try. If you have no success in a recycling attempt do not try it again. There is a chance of an in-flight fire from overheated components.

An easy mistake is to forget to turn on the Alternator Master after starting. If you're going to be departing at night and/or IFR you'll be depending on your instruments while the battery is rapidly being depleted – could be a real hair-raiser.

The Ignition Switch would seem like a truly straightforward thing to use. Just turn it and wait for the engine to start. Too bad it can't be that simple. A couple of members have remarked lately that the starter seems balky at times. When they turn the key the prop initially doesn't move or moves a few degrees and then hangs up. They wondered if there was something wrong with the starter or if the battery was low. They also wondered whether they were doing it wrong somehow. They noted that if they just kept the key turned to the start position the engine would, after a delay of several agonizing seconds, finally begin to crank over. It just didn't feel right to them. They were right about that.

The Starting System, like just about everything on the plane, is made as light as possible which means that it is barely adequate to get the job done. There is a good deal of internal friction in the engine and there are large voltage losses in the cables and connections. What's more, the battery is puny by comparison to the ones in our cars.

Once again, this is because of the need to hold weight down. As I see it, the real wonder is that the plane starts at all. We need to give the plane all the help we can to ease the starting load on the system.

When our guys turned the key and saw little or no initial motion their mistake was to keep holding the key over. Persisting with the attempt to start against a stalled (immobile) starter motor causes an enormous current overload from the battery to the starter. All it accomplishes is to drain the battery in a damaging way and to uselessly heat the system – Possibly overheat and damage the starter, maybe burn out the starter relay.

So, how should they have acted to conserve the system and get the engine started with the least fuss? As soon as they could see that the engine wasn't turning they should have released the key and let the system rest for perhaps half a minute. (The Lycoming Manual says to crank for no more than 5 seconds and then let the system rest for two minutes). Then they could try again for a couple of seconds. If after a third try the engine isn't cranking they should turn off the system, take the key out of the switch and get out and, very carefully, pull the prop through three or four blades to break the initial friction.

This will usually make a start possible if there's life in the battery. It's a good rule to always pull the prop through before a winter start because the congealed oil puts an extra heavy load on the starter and the battery's available energy drops off quite steeply as temperatures drop below freezing. When you do this make sure the brakes are locked and <u>Throttle</u> closed.

3. The Primer: I see more people struggling with starting balky engines at the airfield than any other issue I can think of. It leaves them feeling frustrated, their non-pilot passengers unsure of how safe the whole endeavor might be and, not infrequently, it results in delayed or cancelled trips.

I've haven't had to struggle with a balky or hard to start engine in many years and I'm no hot pilot by any means, I don't know any magic, but I do know engines. I'd like to share what I know. It's not very complicated, not like the ability to start a fire in a fireplace without having to spend an hour on your knees blowing on the damned thing and getting smoke in your eyes. Some guys never "get it" with starting fires, but I guarantee you'll quickly become a great engine starter after a few paragraphs.

It is a truism among mechanics that any engine will start if it has three things: **<u>Compression</u>, <u>Fuel</u>** and **<u>Spark.</u>** Our engines all have excellent compression; they are tested for compression regularly. They have, as was discussed earlier, two magnetos per engine to assure that there will be a spark. What's more, the magnetos will keep on putting out a spark regardless of the condition of the battery. The third necessity, fuel, is entirely under your control. You've already made sure there is plenty of fuel in the tanks when you did your pre-flight. You've gotten a clear indication from the fuel pressure gauge that fuel is being delivered to the carburetor.

Now, all that is left to do to assure that the engine will burst into life when you turn the key is to get some of that fuel – enough fuel -- into the engine's cylinders. There's one way and one way only to deliver fuel directly to the cylinders prior to starting so that ignition will be a sure thing.

Yeah, you guessed it. **The Primer.** It is a very simple, even primitive, little pump consisting of a plunger and a valve. Its one other feature is that it can be locked in the closed position; we'll get back to this item later. The Primer Pump, located down low on the panel, is plumbed into the fuel system so that it can draw fuel up from the tank in current use and supply the fuel under pressure to two of the engine's four cylinders (in the Archer, In the Dakota the arrangement is slightly different). When the Primer is used properly this fuel is sprayed in the form of a fine mist directly into the intake ports of the active cylinders.

The key to easy starting lies in how you use this little pump and how much you use it. One of the peculiarities of the Primer is that it is a bit slow to fill on each out stroke (the pull stroke) and so you must give it the time it needs to fill. In other words pull out slowly and wait a second before you start the delivery (push) stroke. Now the other secret – If you want the engine to start obediently for you, push smartly all the way in on the plunger. You want to assure that there is a vigorous jet of fuel into the intake port, not a slow dribble. This technique gives the best vaporization and the other secret not mentioned in listing the sacred three – Compression, fuel, spark – is that the fuel won't ignite as a liquid. It has to be vaporized to burn.

Okay, now we know how to get the fuel into the engine at the right place and in a useful form. The next item is How Much. Well, it depends crucially on how hot – or how cold the engine is.

Simple rules on this; learned the hard way; If the engine is cold, Ice cold, on a winter day, **Use seven (7) shots of prime.** If the weather is warmer and the engine is cold (hasn't been run for hours or days), **Use five or six (5 or 6) shots of prime.** If the engine is still warm (been run within the past hour in summer or within the past half hour in winter) **Use four (4) shots of prime.**

Additional rule; **When in doubt use more prime.** Remember, since only half the cylinders get primed **You cannot Flood the Whole Engine with the Primer.** The two Cardinal sins of priming are: one; not using it and two; not using it hard enough.

Another important use of the Primer comes into play in very cold weather starting where the Primer is used to substitute for a choke control, which (you'll recall from our initial comparison of aircraft vs. auto engines) is missing from the aircraft engine. The drill goes like this: After priming the engine for a cold start (7 shots of prime) we leave the Primer all the way out and thus full and ready for another squirt. When the engine catches and just begins to run we judiciously shove in on the Primer to provide the extra amount of gas needed to keep it running for the critical first few seconds until the plugs warm up. Bush pilots in real cold environments such as Alaska become virtuosos at playing the Primer. They just keep on pumping the thing for as long as it takes, since that's the only way to keep the engine running long enough to warm up to the point where it will continue to run without this special assistance.

There's one big mistake with the Primer that I left for last, one that can really spoil your whole day. Forgetting to lock the Primer before takeoff can, and almost Certainly, will result in rough running and loss of power. This is the real reason the manufacturer only connected the Primer lines to half of the number of cylinders. They want to make sure that if you forget to lock the thing you'll still have half power.

Think about it – not a good place to be when you're flying. A few weeks ago one of our newer members consulted Steve, our chief mechanic, about a rough running engine that was clearly too sick to fly with. Steve found an unlocked Primer – problem solved. But we need to be sure that every member knows how to use the Primer.

What happens when the engine is run with the Primer unlocked is that the cylinders connected to it suck up a lot of additional fuel through the Primer lines. This extra fuel makes those cylinders run so rich that they can barely operate at all. Effectively you are down to half an engine and a pretty sick one at that.

4. The Engine Instruments: OK, we've finally gotten the engine started and as previously mentioned the first glances are toward the Oil Pressure gauge and the Tach. Now what's next? Well, we'd like to know when the engine is up to sufficient operating temperature for takeoff. Up until quite recently our best way to accomplish this has not been by monitoring a gauge, not even the Oil Temperature gauge. In fact, the manual makes it clear that this gauge is too sluggish to be of any help for this purpose. The Book suggests that we can best determine if the engine is warmed up for takeoff by pulling the throttle all the way back to idle and then shoving it forward to full throttle rapidly. If the engine stumbles or hesitates to take full throttle it is not warm enough for takeoff.

Lately, we've been installing new multi-function instruments to take the place of the old Exhaust Gas Temperature Gauges. The new replacements can be switched from displaying EGT to showing either Outside Air Temperature or, at pilot's discretion, Cylinder Head Temperature. These new instruments are not in all of our planes as of this writing but they will be installed as time and budget allow. They provide another option to assess the engine's condition, but I suggest that the throttle exercise will remain the most valuable indicator of engine readiness. One caution, when performing the throttle exercise we don't want the engine screaming away at max RPM during this check. As soon as it becomes obvious that the engine will take the throttle smoothly you pull it back to low RPM. You can perform the whole item without exceeding 1500 to 1700 RPM.

Well, we've gotten the engine started. Our flight lies ahead of us. There's a lot more to discuss on the subject of Power-Plant Management as our flight proceeds but that will be the subject of Part Two, to be presented in the near future.

Notes