SUPERIOR AIR PARTS

# ENGINE MANAGEMENT 101

Proven tips to extending your engine's life while lowering your operating costs.

**BY BILL ROSS**

VICE PRESIDENT, PRODUCT SUPPORT, SUPERIOR AIR PARTS

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The aim of this book is to entertain, educate and enhance the pilot's, aircraft owner's and mechanic's awareness about the operation and maintenance of a piston aircraft engine. At no time does this information replace the procedures within any aircraft's Pilot Operating Handbook (POH), Pilot's Guide (PG) or FAA requirement. 

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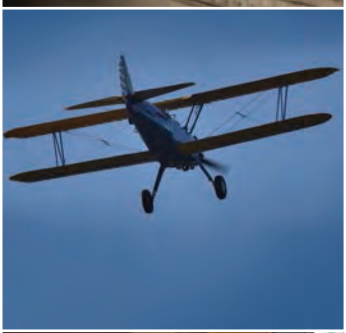
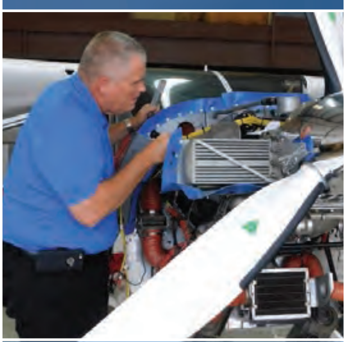
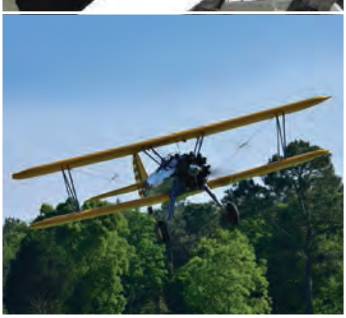




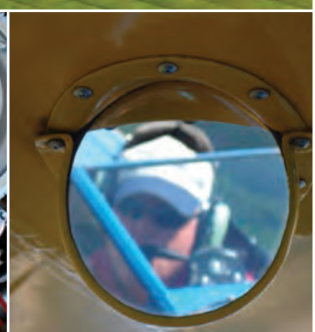



GO BAMA GO


CENTER


QUALITY
ASSURANCE


FIRE EXTINGUISHER

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IRE EXTINGUISHER

# Who the hell is Bill Ross?

The short answer is I'm an airplane owner and lover of aviation just like you. Ever since I was a young boy I was very interested in anything related to aviation. Of course, being born at Patrick Air Force Base and the son of an Aeronautical Engineer, I didn't really have any options, did I?

Like most kids, I built many, many model aircraft and always liked going to the airport just to watch the airplanes. I remember as a child thinking, "If I could just touch an aircraft or climb into the cockpit it would be so cool."

After my father got out of the Air Force, we moved to a rural area of southern Alabama where I grew up on our family farm. There, I learned about hard work, pride, integrity and became knowledgeable of things mechanical out of necessity. Our family was not rooted in wealth and did not have the luxury of being able to call a mechanic to repair machinery or anything else for that

> "My dad saw that I was headed down the wrong road and asked me to spend a Saturday morning with him. That day would change my life forever."

matter. So, when a tractor or piece of equipment broke, we had to fix it out of pure necessity.

I was just a boy when I started repairing, overhauling, welding and modifying many different types of equipment. I was taught responsibility and perseverance through working on the farm. Even though the work was hard, I was a lucky kid to be brought up that way.

During my high school years I began to believe that a life of farming and tractor maintenance was what the future held for me. I had no real interest in education and my grades reflected that feeling in no uncertain terms. When my grades began to drop I started to get into a lot of trouble at school. Nothing major; just mischief that kept me tied up in the principal's office on a regular basis.

Back then, the classrooms were not air conditioned, but the front office and library were. I did not really care for spending time in the library, so the front office was the coolest spot. The principal and I were almost on a first name basis.

My dad saw that I was headed down the wrong road and asked me to spend a Saturday morning with him. That day would change my life forever!

This was not the first time my dad asked me to go for a drive and I knew he could administer an ass chewing better than anyone. He had been after me to improve my grades and consider going to college. I thought this Saturday would be the same old deal.

## My dad's BIG surprise

Anyway, on this particular Saturday we drove to Ocean Springs, Mississippi and pulled up to an airport located in Gulfpark. We stopped and walked around the airport looking at airplanes and finally came to a Cessna 172 that had the doors open. N6270D was the airplane registration and my dad reached in the cockpit and started doing things: turning on the master switch, lowering the flaps, getting out the Curtis drain cup and fiddling with other items in the cockpit.

I said to my dad, "You better stop messing with this airplane, it looks like someone is about to fly it." My dad replied, "Yes, we are!" Unbeknownst to me, my dad had learned to fly and obtained his private pilot's license – all while keeping it under the radar from everyone in the family.

I remember being very surprised and thought this was a big joke at first. However, when the owner of the airport called my dad

"I said to my dad, "You better stop messing with this airplane, it looks like someone is about to fly it." My dad replied, "Yes, we are!""

by name, I knew this was for real. We took off and flew around our home in south Alabama and landed at the controlled airport where we got a tour of the Flight Service Station. I was so amazed at the flight and everything that was involved to make it happen.

I knew right away that flying and some type of career in aviation was for me. You may be interested to know that after that flight I found a purpose and turned my life around. I started making very good grades in school and began looking at what it would take for me to have a career in aviation.

## I get my wings

As quickly as I could, I went and got my 3rd class medical, student pilot certificate, radiotelephone operator's permit and began taking flying lessons at the local airport. I soloed with only 4.3 hours flight time and went on to earn my private pilot's license – all this and I was still only a junior in high school.

On a side note, I have to tell you that having your pilot's license in high school makes for an interesting date on prom night!

Anyway, after graduation I immediately enrolled in aviation maintenance school and went on to obtain my commercial, instrument,

"On a side note, I have to tell you that having your pilot's license in high school makes for an interesting date on prom night!"

multi engine and instructor ratings. Subsequently, I worked as a fight instructor and charter pilot/mechanic for many years and along the way I earned a bachelor's of science degree from the University of South Alabama (GO Jaguars!).

## Thousands of hours of flight time and still loving every minute of it

As a charter pilot, I flew many different types of piston and turbine aircraft. However, I was and still remain at heart primarily a piston aircraft driver. Through the span of 32 years I have had the opportunity to be mentored by and work with some of the most talented and knowledgeable people in the industry. To me it has never been just a job but rather a way of life. My passion for the industry goes deeper than most will ever know.

## So why did I write this book?

Throughout my aviation career, I have read and heard a lot of myths and stories about what is best for the internal combustion aircraft engine: the old wives tales about how you should maintain and operate your engine and the tall tales about the demons that live in and around your engine.

I have had the unfortunate task of seeing many incidents and accidents that were caused in some part by the pilot's following some these myths and improper maintenance practices.

The purpose of this book is to dispel many of the myths and untruths regarding engine care. I also want to promote best practices that will help ensure the safety of you and your passengers, while at the same time saving you money in unscheduled maintenance costs. Sure, there will be many that question some of the things in this book. But I learned a long time ago that asking questions is a good thing.

I am an aircraft owner too and want to maximize efficiency and minimize life-cycle costs associated with my aircraft engines. I fully understand the ramifications of having to go to the financial

"The purpose of this book is to dispel many of the myths and untruths regarding engine care."

controller at my house (wife) and request a purchase order number for expenses to the aircraft. The expenses should be planned as part of best practices and not unplanned because of neglect.

It has taken many years of experience in customer service, product development and technical product support to put this book together. Additionally, there have been times where I learned the hard way about doing things the right way.

Many of the myths, stories and untruths I have come to hear over the years are universally not seeded by any true technical data or engineering tests. During my career I have had the opportunity to work alongside some brilliant people that truly developed me. I would now like to take that information and experiences and share with you some tips that will save you money and increase the safety and reliability of your aircraft. The highlight of my aviation career is getting out and speaking with aircraft owners and pilots like you.

**The book is free. The information can be priceless…**

I have been asked many times to provide copies of my presentations on aircraft engine management, so I thought why not consolidate all that information into a little book?

Although I love speaking to audiences about aircraft and engines, I used to be terrified of public speaking. I dismissed that fear when I was overcome with

> "The first step to making flying more affordable is the proper operation and management of your engine. That's what this book is all about."

a true passion about promoting general aviation and helping other aircraft owners.

Today, as the Vice President of Product Support for Superior Air Parts, Inc., I am fortunate enough to have the opportunity to put all of my thoughts, knowledge and information into my presentations and this book.

Everyone at Superior is dedicated to providing its customers with the products and information they need to make flying and aircraft ownership as affordable as possible. The first step to making flying more affordable is the proper operation and management of your engine. That's what this book is all about.

My writing is not intended as a guidebook for you as owners to perform your own maintenance and in no way should be used as a substitution for an experienced mechanic or actual technical data from the respective manufacturers.

However, it is my sincere hope that reading these sections will provide a basis for understanding more about your aircraft engine, how to be kind to it and communicate effectively with your mechanic. Asking the right questions and working well with your maintenance provider will save you money in direct operating costs and, most importantly, improve safety.

Safe flying,

Bill

Bill Ross

# Choosing the right mechanic.

It was a dark and stormy night, and after a long flight from Red Wing, Minnesota to Mobile, Alabama the 23 year old, still wet-behind-the-ears charter pilot makes a very nice landing. After shutdown, as claps and cheers ring from the rear of the Beechcraft A65 Queen Air, he is hailed as a hero by his grateful passengers.

What those passengers did not know was the pilot did not turn on the engines' boost pumps for takeoff, and while skirting thunderstorms and traversing over dense layers of low visibility and fog, he missed several radio calls from Air Traffic Control. No matter, the pilot was solely graded on his ability to end the flight with a smooth landing.

In these conditions any mechanical issue could have easily resulted in disaster. Truth be told, while the passengers praised

> "Looking back, I should have split the tip with the mechanic. After all, he had kept me from having to excercise my limited emergency procedure skills."

the pilot, the real hero of that day was still busy out in the hangar getting another airplane ready for tomorrow's flight.

I was that young pilot soaking up all the credit for my talent and safety. I even received a $50.00 tip, which back in 1987 was big money – enough to buy groceries for more than a week. Looking back, I should have split the tip with the mechanic. After all, he had kept me from having to exercise my limited emergency procedure skills.

## Mechanics: The *Rodney Dangerfields* of aviation

But I, like my passengers, simply took for granted the work that the aircraft's mechanics performed. Most pilots still do. Have you ever seen a pilot or passenger exit an airplane and make their way through the lobby to the maintenance shop just to shake the hand of the mechanic? Hell no!

Pilots, on the other hand always tend to get the credit, glamour and tips. They're the ones standing there chatting with the pretty girl behind the counter at the FBO, while the mechanic is working hard out in the cold hangar to keep everyone safe. No wonder mechanics have a reputation for being grumpy.

In fact, the majority of aircraft owners cannot believe the *criminal* type hourly rate they have to pay for maintenance. Although it probably costs more per-hour to have their RV or boat serviced than their aircraft, they still complain. You know who you are.

"In fact, the majority of aircraft owners cannot believe the *criminal* type hourly rate they have to pay for maintenance."

That being said, I have found many owners that believe that anyone who has an A&P certificate is automatically *qualified* to perform any task required on their airplane. And, when they find a mechanic that is qualified and inexpensive – well, it's like Christmas morning.

## Good mechanics deserve your respect

Throughout my aviation calling, I have enjoyed careers as both a professional pilot and a professional aircraft mechanic. And in doing so, have gained the utmost respect for the dedication and commitment it takes to be a diligent, qualified and well-rounded mechanic.

> "My third career as an aircraft owner has also taught me that pilots and mechanics must work very closely together."

My third career as an aircraft owner has also has taught me that pilots and mechanics must work very closely together. We must be able to communicate effectively. One of the purposes of my writing this chapter is to help bridge the gap between the mechanic and pilot so we can all work together in the interest of safety and reliability.

Unfortunately, not all mechanics are created equal. Some have expertise in certain areas and are oblivious in others. However, at the heart of each aircraft mechanic out there, is the desire to do a good job and keep their respective customers and passengers safe. There are very few mechanics out there that can function right out of the box for every aircraft made. Training and experience is paramount to the qualified mechanic.

And as an aircraft owner, it is your responsibility to choose the right mechanic for your situation.

## It's okay to ask questions

As owners, it's okay for us to ask questions to help determine whether we have found a competent mechanic. Just because someone possesses an Airframe and Powerplant certificate or even an Inspection Authorization, does not mean that they are qualified to work on your particular aircraft.

In fact, in an effort to provide total transparency, I must tell you that I am both an A&P and IA and that they're not that hard to earn. In order to qualify for an Airframe and Powerplant certificate, you must be 18 years of age, able to read write and speak the English language, pass a written, show 30 months experience (not well defined) and pass the oral/practical test. I assure you during testing there is no real evaluation of the candidate's knowledge of your particular aircraft.

Like passing your Private Pilot's check ride, obtaining an Airframe and Powerplant certificate should be viewed only as a license to learn. When I graduated, it was clear I had very little knowledge about piston engines. The only engine I touched in aviation maintenance school was a Continental O470-11 installed in an L19 Birddog. Not surprisingly, some 32 years later, I have not worked on an L19 since I left school.

Honestly, even after completing A&P school I personally had no business overhauling engines. I had no idea about proper fuel

> "Today, even after thousands of hours in the air and 32 years as a A&P, I am still learning."

system calibration or magneto maintenance. Training had taught me just enough to be *dangerous*. Literally. It took years of piloting and maintaining to learn the specifics of operating and maintaining piston engines. Today, even after thousands of hours in the air and 32 years as an A&P, I am still learning.

### You just don't know what you don't know

Before I go any further, I must share with you a true story that was a very real life lesson in the value of having qualified and trained personnel maintain your aircraft. (I actually told this story at the FAA's Propulsion Directorate in Boston, Massachusetts. Of course, I inquired about the Statute of Limitations on being a dumbass.)

Anyway, while still in high school, I had already developed a desire to become a pilot and an aircraft mechanic. I had befriended a local airport family and began hanging around the airport. My family felt it was good for me and kept me out of trouble. Each Saturday and Sunday from sunup to sundown, I would help wash airplanes, cut grass, change oil and do anything else the owner of the airport decided was the priority of the day.

My "pay" was 30 minutes flight time in their J3 Cub. I thought I was getting the better end of the deal! One day my friend,

> "With regard to torque specifications, without a calibrated torque wrench, we relied on our tractor experience, "tighter than hell and a quarter turn.""

another aspiring pilot/mechanic, and I heard that his father's Cessna 182 had a cylinder with very low compression.

Both of us had worked on tractors, lawn mowers, motor-bikes and go-karts, so it seemed logical that we could change the cylinder. It's just an engine; how hard could it be? Neither of us had an A&P, a torque wrench, or a clue about the right way to remove and replace the 182's cylinder.

The cylinder was removed and we replaced it with an overhauled unit from a nearby cylinder shop. With regard to torque specifications, without a calibrated torque wrench, we relied on our tractor experience, "tighter than hell and a quarter turn." Our thought was that would provide more than adequate torque for any piece of machinery we were wrenching on.

The engine seemed to run very well after the cylinder change and we were very proud of our accomplishment. Then some 35-engine hours later, my friend and co-conspirator was at the controls of the airplane when the engine experienced a catastrophic failure.

Luckily, he had a very experienced pilot with him and they landed at our home airport without causing any further damage. The engine, however, was completely destroyed.

The cause of the catastrophic failure event was determined to be our improper torquing of the through bolt during the cylinder's installation.

Therefore, I speak from experience when I talk about having qualified persons working on your aircraft. You should take comfort in knowing both my cohort and I now hold A&P licenses with

"Mechanics must have specialized training and experience on specific tasks and items for which they intend to perform maintenance."

Inspection Authorizations. We also now have calibrated torque tools and subscribe to the technical data for any aircraft for which we perform maintenance.

A sad, but important sidebar to this story is that even after graduating from A&P school I probably still would have not utilized correct methods and practices when changing the cylinder. Mechanics must have specialized training and experience on specific tasks and items for which they intend to perform maintenance.

## Not every mechanic is the *right* mechanic

Even today, when talking to many aircraft owners, I often hear them say, "Oh he's a good mechanic because he worked on jets for 44 years" or, "He's a great mechanic and has an A&P/IA."

Heck, I know airline pilots with tens-of-thousands of flight hours in big Boeings, but I wouldn't let them loose in my Stearman without many hours of type-specific training. The same goes for finding a qualified mechanic.

1. Does he/she understand my piston engine or aircraft? (Not all piston aircraft engines are the same as many aircraft are not the same.)
2. Does he/she have specific product training for my aircraft and engine?
3. Does he/she have the proper tools, equipment and technical data to be caring for my aircraft and engine?
4. Have you asked to see his or her resume of experience in maintaining aircraft like yours?

Again, as an aircraft owner it's your responsibility to ask any prospective maintenance technician some key questions. While the majority of mechanics have the proper training and technical data for the aircraft they service, too many do not. Subscriptions to some of the technical publications can be cost prohibitive for many maintenance providers, especially those working at smaller shops or freelance. (Always beware of the mechanic what works out of his trunk.)

Over the years I have had the unfortunate task to assist too many owners that were a victims of improperly trained or insufficiently prepared mechanics. Unfortunately, these lessons have been very costly to the owners, not to mention having possibly resulted in an accident or, more likely, reduced the life cycle of their engine.

Having the cheapest person work on your aircraft may not be the best practice and may actually end up costing you more through mistakes and additional unscheduled maintenance.

## When all else fails, follow the manufacturer's instructions

Although I can't take credit for the following quote I think it sums up the argument for doing exactly what manufacturers recommend: ***"The purpose of scheduled maintenance is to prevent unscheduled maintenance."***

In fact, I like it so much I use it as my go-to answer when aircraft owners ask me if they really need to comply or do this recommended maintenance procedure?

Think about it: Why would a manufacturer recommend specific tasks if it were not in your best interest? I am not talking about changing the air in the tires but rather items that can extend the life and improve reliability of the product.

Aircraft engine manufacturers really have your best interest and safety in mind when maintenance recommendations are made.

Therefore, you as an owner have the responsibility to ensure your mechanic has the proper training, tools and data to maintain and repair your aircraft.

Many mechanics can form their own opinions about how to operate your aircraft; how to obtain maximum performance; how to operate it most efficiently; or how to increase your engine's durability. My experience is that it's a good bet that these same mechanics do not understand the importance of following manufacturer's recommendations and lack the proper training to know the difference.

In fact, and I find this incredible, that there are actually many advocates in the industry that propose not following manufacturer recommendations at all. On top of that, they make their living proclaiming this and all the while telling you they will save you money. So, before you follow their recommendations, ask yourself:

1. If I have an incident or accident with my aircraft, do I want to stand in a courtroom and say I did not comply with all recommendations set forth by the manufacturer?
2. Will these said "experts" follow you and stand in the courtroom by your side?
3. Will the advocate cover costs if you have an off airport landing? If you ruin your engine? If you are hurt?
4. Has your "expert" ever really worked as a mechanic?
5. Are they sure you will not be voiding your warranty by not adhering to manufacturer's instructions?

The short answer to all of the above is, "no."

## Engine maintenance in the Internet age

In our world of social media there is much information at our fingertips. The trouble is, how do we determine what information is credible and based on sound engineering and tested data? If it's on the Internet it must be true. Right? Wrong!!

Sure, much of the information sounds good and may actually make sense but could lead us down unsuitable paths. Manufacturers are bound by federal regulations to publish instructions for continued airworthiness. Manufacturers' service and maintenance recommendations are in no way based on opinions, assumptions or the idea of creating "busy work" for mechanics and unnecessary expenses for owners.

I can tell you first-hand that the manufacturer's recommendations are based on sound engineering tests, durability testing, product field performance information and good practices. There

"I am not suggesting that you overhaul or replace your engine the minute you hit TBO, but the manufacturer is obligated to recommend a time."

are no kickbacks to the engine manufacturer when you change your oil or clean your fuel injection nozzles.

Keep in mind the many "experts" in the aviation industry recommending that you not comply with manufacturer's recommendations are not engineers and do not have access to any of the test data that certified your engine! It's just their personal opinion.

I am not suggesting that you overhaul or replace your engine the minute you hit TBO, but the manufacturer is obligated to recommend a time. And that recommendation is based on their knowledge of the engine and its components.

Clearly you can fly past TBO safely, provided you follow manufacturer's recommendations for determining continued airworthiness of the engine. You can bet your last dollar, that those owners and maintenance providers that follow manufacturer's recommendations will beat others to TBO and beyond on overall costs and improved safety.

## A word about Certified Repair Stations

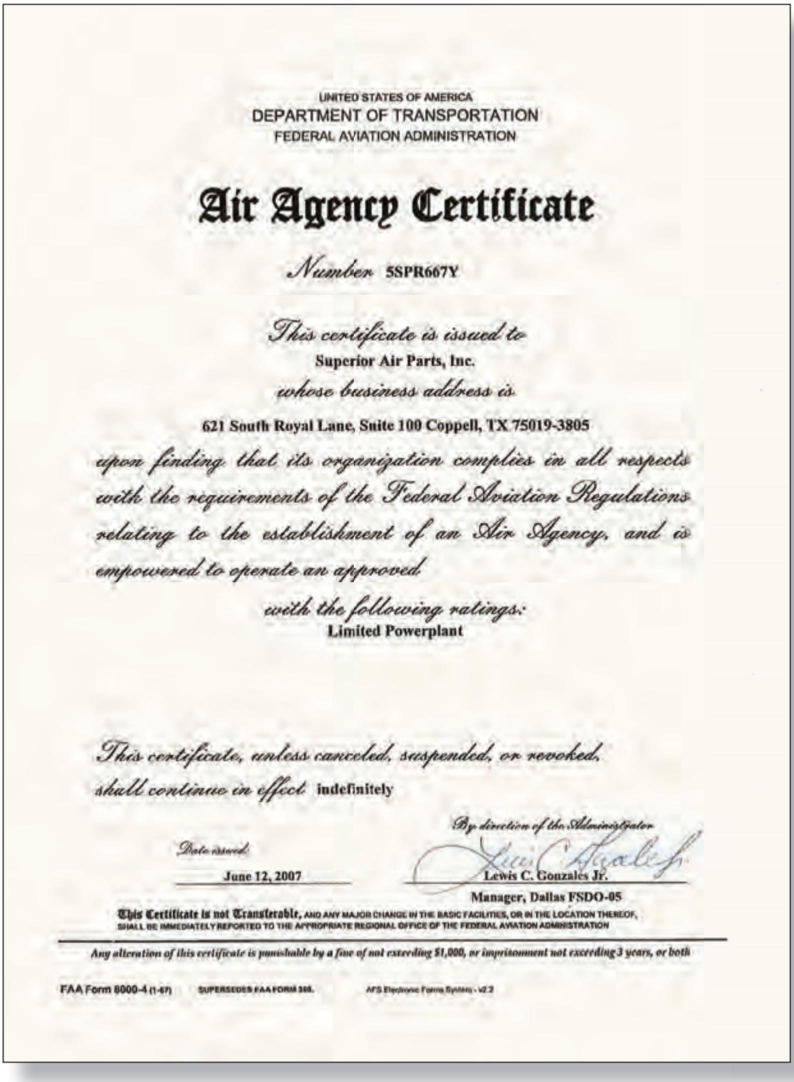
If you don't have total confidence in your local independent mechanic an alternative option we have as owners is the Certified Repair Station. These maintenance, repair and overhaul (MRO) facilities have to undergo very high standards in order to obtain repair station approval from the FAA.

It is an actual five-step process that includes a pre-application, formal application, document compliance review, demonstration and inspection and ultimately, certification.

Repair Station privileges and limitations can be found under FAR part 145. These repair facilities often specialize services they offer. I am not suggesting you should always have maintenance or repair performed by a certified repair station but you can be assured they are held to a higher level than a non-certified facility. Of course, these facilities typically can have higher hourly rates than non-certificated shops, so cost-conscious owners often overlook them.

Repair Stations are easy to identify by the posting of their Air Agency Certificate like the example on page 20.

Remember, you will never save any money by finding the cheapest mechanic to maintain your aircraft.



UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

**Air Agency Certificate**

*Number* 5SPR667Y

*This certificate is issued to*
Superior Air Parts, Inc.
*whose business address is*
621 South Royal Lane, Suite 100 Coppell, TX 75019-3805

*upon finding that its organization complies in all respects with the requirements of the Federal Aviation Regulations relating to the establishment of an Air Agency, and is empowered to operate an approved*

*with the following ratings:*
Limited Powerplant

*This certificate, unless canceled, suspended, or revoked, shall continue in effect* indefinitely

*Date issued:* June 12, 2007

*By direction of the Administrator*
Lewis C. Gonzales Jr.
Manager, Dallas FSDO-05

This Certificate is not Transferable, AND ANY MAJOR CHANGE IN THE BASIC FACILITIES, OR IN THE LOCATION THEREOF, SHALL BE IMMEDIATELY REPORTED TO THE APPROPRIATE REGIONAL OFFICE OF THE FEDERAL AVIATION ADMINISTRATION

*Any alteration of this certificate is punishable by a fine of not exceeding $1,000, or imprisonment not exceeding 3 years, or both*

FAA Form 8000-4 (1-67) SUPERSEDES FAA FORM 398. AFS Electronic Forms System - v2.2

"Remember, you will never save any money by finding the cheapest mechanic to maintain your aircraft."

# Improving engine operations and extending engine life.

Over the years, the topic of engine leaning has been overcomplicated to the point where many pilots have lost sight of the fundamentals of how to properly manage their engine – and it's critically important.

Good engine management practices will help prolong the life of your engine, reduce operating costs and improve safety. The problem is, there are numerous articles and white papers packed with myths based on unsubstantiated technical data. To say the subject can be very confusing to most pilots is an understatement.

The truth is, proper engine management is pretty easy. In this section, I will discuss the subject in a very simple and understandable way and provide a foundation based on engineering test data, engine certification testing and the engine manufacturer's recommendations.

## What if your car's engine was in your airplane?

Think for a moment about what we demand from our aircraft engines. Our wish list has them being powerful, lightweight, economical, good looking, and requiring no unscheduled maintenance until its overhaul time – or beyond. Basically we want a bulletproof power plant that just runs and runs and runs.

But, let's compare the aircraft engine to the average automobile engine. In our cars, we typically use about 10 percent of the engine's rated power while cruising the interstate with the air conditioner on.

Aircraft engines are treated a little differently. Aircraft engines are operated between 65 and 100 percent of their rated power at cruise. So if we were to treat those aircraft and auto engines equally, we would drive our auto everywhere with our right foot on or near the floorboard. I doubt if your engine or car would last long under those circumstances.

Now, if the average aircraft owner flew 1,000 hours and cruised at 200 knots, they would have traveled 200,000 miles. At 1,000 hours we would consider that a "mid-time engine" and not expect to have to spend any money on unscheduled maintenance.

However, if the same owner drove his luxury SUV 200,000 miles and needed a new transmission or major engine repair, he wouldn't think twice about it. Looking at it that way, I think it is safe to say we demand a lot of reliability from our aircraft engines. And because of that, we should do our best to take better care of them.

When an aircraft engine manufacturer certifies an engine it is based on many hundreds of hours of engineering durability testing, calibration, detonation avoidance testing, propeller integration, altitude tests and vibration analysis. With an investment like that, it's easy to see that piston aircraft engine manufacturers don't take reliability, maintenance or your safety lightly.

## Learning to love leaning your engine

Back in 1986 I secured my first aviation job with a charter outfit in Mobile, AL. I was a pilot, mechanic, line boy and "hey boy" watching over its fleet of Beechcraft Queen Airs and Barons.

Up to this point I really had no idea how to lean an aircraft other than the old method we were taught in flight school of leaning to roughness and turning the mixture in until smooth again. In fact, up until this point, I had flown nothing more than Cessna single-engine aircraft as a flight instructor. The Beechcrafts were much more complex than I was used to.

Early on, I thought that the combination of flying longer charter legs and being in the right seat with an experienced twin-engine pilot would surely teach me more about engine leaning. Well, not so much.

During the first flight out on a long trip the chief pilot set cruise and pulled the mixtures back to an even fuel flow on both engines, and away we went.

Seeing an old pro do that I thought, "Oh hell, it is simple!" And that's the way I leaned the engines for years. But, as the price of Avgas  and the hours on the engines kept rising, it suddenly

"Reading the manuals: What a novel concept."

occurred to me that maybe I should read the operations manual for the aircraft. I wonder what the experts at Beechcraft or Lycoming/Continental have to say about the subject? Reading the manuals: What a novel concept!

Anyway, after doing a little research on the subject, I found that we pilots could save the charter company large amounts of money by – depending on the length of the mission – either flying at best power (rich of peak) or best economy (lean of peak).

I should point out that best economy in some aircraft is actually located at the engine's peak exhaust gas temperature (EGT).

When it comes to your engine's health you should consult your POH to determine best economy settings for your aircraft.

The particular requirements of the mission at hand are often lost when thinking about engine management. It seems today our true mission is to obsess over engine kindness, while saving as much fuel as possible, all while cruising as fast as possible.

As we continue to look at proper engine flight management techniques, I would like you to think of engine leaning in a new way: Think of it as "Engine Flight Management for Maximum Efficiency and Durability."

Keep in mind that, depending on the mission the most efficient way to operate the aircraft's engine is either best power or best economy. It's up to you to select the right one for every flight.

## Engine flight management for maximum efficiency and durability

In order to better understand engine management, it is key to define a few terms that are critical to proper engine leaning and operations.

### Pre-ignition 101

Pre-ignition is simply the igniting of the fuel air mixture before the specified point during the compression stroke. In most aircraft engines, the ignition event is timed somewhere between 20 and 32 degrees before top-center depending on the engine make and model.

This means the spark occurs 20 to 32 degrees before the piston reaches the top of the compression stroke. There are mechanics and owners that attempt to gain more power from the engine by purposely advancing the timing. Having the spark occur before the specified time can result in increased power but it can come with a price. It can destroy an aircraft engine in very short order.

The more common way for pre-ignition to occur is through a faulty ignition system. Therefore it is very important to service magnetos and have the ignition timing checked at the specified intervals set forth the system's manufacturer.

Many instances of pre-ignition situations that I've seen were due to an owner's complete disregard for the ignition system manufacturer's maintenance recommendations. I know because I have worked with the aircraft's owner and the NTSB to perform the forensics on these incidents.

Keep in mind that just because we have a good magneto check before takeoff does not always indicate the complete health of our ignition system.

"Keep in mind that just because we have a good magneto check before takeoff does not always indicate the complete health of our iginition system."

Contrary to what you may hear from experts, lean of peak magneto checks or engine monitors should never be used as a substitute for following manufacturer's instructions for continued airworthiness.

Other causes for pre-ignition can be hot spots that develop and act as igniters or fractured spark plug electrode insulators. Also be aware that pre-ignition can lead very quickly to detonation.

## Detonation

Detonation is the spontaneous combustion of the fuel air mixture and results in extreme pressures being exerted against the piston, connecting rod, crankshaft and combustion chamber. It is a very real phenomenon that we want to avoid when leaning or operating any of our engines.

Detonation is the pinging sound we often hear in our automobile engines as the shock waves resonate through the combustion chamber. And while it's annoying in your car, it can be devastating to your aircraft engine's performance.

Unlike your car, your aircraft's engine is not equipped with anti-knock sensors that can change timing or fuel injection duration in order to suppress detonation. Detonation is characterized by very low exhaust gas temperature and very high cylinder head temperature.

And it's not always the same: Detonation can be very light and cause no engine damage or, in the worst cases, very heavy and result in extensive engine damage. In Figure 1 you will see a piston that's been destroyed by pre-ignition/detonation.

Notice the periphery of the piston was exposed to such extreme heat as to actually melt away a portion of the material. In a detonation event such as the one depicted, the engine is

*FIGURE 1*
*Piston destroyed by excessive pre-ignition detonation.*

exposed to extreme pressure blow-by, therefore raising the internal crankcase pressure.

The increased crankcase pressure causes the evacuation of the oil supply out through the breather, resulting in engine oil starvation. When this happens, it can ruin your day by causing the fan on the front of the aircraft to stop turning.

"When this happens it can ruin your day by causing the fan on the front of the aircraft to stop turning."

As engine manufacturers, we never want this to happen and go to great lengths to make sure it doesn't.

By the way, if your engine ever suffers from a detonation event, it is recommended by all manufacturers that it be completely disassembled for inspection. This is what is often referred to as an Inspect and Repair as Necessary (IRAN) event.

As you might well expect, depending on the amount of internal damage, your typical IRAN inspections can be very expensive. It is not uncommon to have virtually no salvageable parts from an engine that has experienced a significant detonation event.

The only way to stop a detonation event is to quickly reduce power and push the mixture to full rich. If you see cylinder head temperatures begin to rise quickly and uncontrollably, you may be near detonation and should take immediate steps to suppress the situation.

## What causes detonation?

Detonation can be caused by many factors and surprisingly its root is not well understood by a lot of general aviation mechanics. Causes for detonation can be improper leaning techniques, incorrect ignition timing, internal magneto malfunction or improper fuel type or fuel contamination.

Recently, I received a call from an aircraft owner and his mechanic. They reported a defective piston that "broke up" and they demanded a replacement cylinder and piston. To help me better understand their issue, I requested the mechanic send me a photograph of the alleged defective piston.

Not to my surprise, what I was provided was clearly a piston that had suffered the effects of detonation. The piston was not broken up, but rather it had melted. The scary part of this story is the mechanic was going to do nothing more than change the cylinder and send the customer on his way.

"The piston was not broken up, but rather it had melted."

I immediately called the owner and mechanic and told them the engine has experienced a pre-ignition/detonation event and that it should be completely disassembled for inspection. The mechanic became defensive and was oblivious to the seriousness of the event that had taken place.

After finally agreeing to an engine examination, it was found that during engine installation the mechanic removed the accessory drive in order to install a new vacuum pump.

In doing so, he moved the accessory drive gears, which resulted in the ignition timing on the right magneto to be advanced to 65 degrees before top-dead-center. This mistake ultimately led to the aforementioned pre-ignition/detonation event and the engine's untimely destruction.

Can you imagine what would have happened had the mechanic been allowed to just replace the damaged cylinder?

He would have sent the owner on his way and the event would have occurred again. The second time could have resulted in total loss of the aircraft or even worse – loss of life. Right now, the only thing the owner has to face is an expensive repair. I hope the mechanic had good general liability insurance.

Back in Chapter 1, I discussed the proper way to find the right mechanic for you and your aircraft. This mechanic came highly recommended because he has been working on jets for over 20 years. Sure, that is impressive, but what was his piston experience? Apparently, it wasn't much.

## Understand the cause: Eliminate the result

I have worked with many aircraft owners that have experienced detonation, and universally they want to call their attorney before they call their mechanic or the engine manufacturer.

And without a doubt, every situation is the same – they all claim that a manufacturing or material defect has led to the detonation event. I guess that is the culture we live in these days. The fact is there was always some kind of catalyst that set the detonation event in action, and in the vast majority of cases it was not the result of some manufacturing or material defect.

Instead of wasting time and money on needless litigation, the owner/operator should be concentrating on immediately determining what caused the event. Detonation is not something you want it to happen again. Chances are the attorneys that are contacted cannot determine the cause and will only delay finding it. (For those of you who may be attorneys or married to one, I apologize to you but remain steadfast to my opinion in the interest of safety.)

## What is maximum recommended cruise power?

By definition, Maximum Recommended Cruise Power (MRC) is, "the power setting at or below, which full leaning authority is safe, allowable and engines are tested for durability." This maximum setting can be found in your POH or engine operations manual.

This term should not be confused with Maximum Continuous Power (MCP), which is the power setting the engine can run 24/7 in a full rich condition. Some engines have a five-minute limit

"There is always one in the audience that wants to "stump the chump." Lucky, me: I'm always the chump!"

for takeoff power and then a maximum continuous power setting thereafter.

In some POHs, there are charts that have the upper end manifold pressure and RPM settings clearly defined. I remember a seminar in which an A36 Bonanza owner began to challenge me that his POH did not have a maximum cruise power setting. Well, chart on page 31 comes directly from the A36 POH and the MCP settings are clearly defined in the chart. There is always one in the audience that wants to "stump the chump." Lucky, me: I'm always the chump!

## The manufacturers really do care!

When engine manufacturers certify engines, they must prove the engine is safe from detonation at takeoff high power

# CRUISE POWER SETTINGS

75% MAXIMUM CONTINUOUS POWER (OR FULL THROTTLE) 2500 RPM
3400 POUNDS

| PRESS. ALT. | ISA −36°F (−20°C) | | | | | | | STANDARD DAY (ISA) | | | | | | | ISA +36°F (+20°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IOAT | | MAIN. PRESS. | FUEL FLOW | | TAS | CAS | IOAT | | MAIN. PRESS. | FUEL FLOW | | TAS | CAS | IOAT | | MAIN. PRESS. | FUEL FLOW | | TAS | CAS |
| FEET | °F | °C | IN HG | PPH | GPH | KTS | KTS | °F | °C | IN HG | PPH | GPH | KTS | KTS | °F | °C | IN HG | PPH | GPH | KTS | KTS |
| SL | 27 | -3 | 23.9 | 91.4 | 15.2 | 156 | 162 | 63 | 17 | 24.6 | 91.4 | 15.2 | 160 | 160 | 99 | 37 | 25.1 | 91.4 | 15.2 | 163 | 157 |
| 1000 | 24 | -5 | 23.6 | 91.4 | 15.2 | 158 | 161 | 60 | 15 | 24.3 | 91.4 | 15.2 | 161 | 157 | 96 | 36 | 24.8 | 91.4 | 15.2 | 164 | 156 |
| 2000 | 20 | -7 | 23.4 | 91.4 | 15.2 | 159 | 160 | 56 | 13 | 24.1 | 91.4 | 15.2 | 162 | 156 | 92 | 34 | 24.6 | 91.4 | 15.2 | 165 | 155 |
| 3000 | 17 | -9 | 23.1 | 91.4 | 15.2 | 160 | 159 | 53 | 12 | 23.8 | 91.4 | 15.2 | 164 | 157 | 89 | 32 | 24.3 | 91.4 | 15.2 | 167 | 154 |
| 4000 | 13 | -11 | 22.8 | 91.4 | 15.2 | 162 | 156 | 49 | 10 | 23.5 | 91.4 | 15.2 | 166 | 156 | 85 | 30 | 24.0 | 91.4 | 15.2 | 168 | 153 |
| 5000 | 10 | -12 | 22.5 | 91.4 | 15.2 | 163 | 157 | 46 | 8 | 23.2 | 91.4 | 15.2 | 166 | 155 | 82 | 28 | 23.7 | 90.5 | 15.1 | 169 | 151 |
| 6000 | 6 | -14 | 22.2 | 91.4 | 15.2 | 164 | 156 | 42 | 6 | 23.0 | 91.4 | 15.2 | 166 | 154 | 76 | 26 | 23.6 | 89.7 | 15.0 | 169 | 150 |
| 7000 | 3 | -16 | 22.0 | 91.4 | 15.2 | 166 | 155 | 39 | 4 | 22.6 | 89.7 | 14.9 | 166 | 151 | 75 | 24 | 22.6 | 86.7 | 14.4 | 166 | 145 |
| 8000 | -1 | -16 | 21.7 | 89.6 | 15.0 | 166 | 153 | 35 | 2 | 21.7 | 86.9 | 14.5 | 166 | 148 | 71 | 22 | 21.7 | 84.0 | 14.0 | 166 | 143 |
| 9000 | -5 | -20 | 20.8 | 86.9 | 14.4 | 164 | 149 | 31 | 0 | 20.8 | 84.1 | 14.0 | 165 | 144 | 67 | 20 | 20.8 | 81.3 | 13.6 | 165 | 139 |
| 10,000 | -8 | -22 | 20.0 | 83.7 | 13.9 | 163 | 146 | 25 | -2 | 20.0 | 81.0 | 13.5 | 163 | 140 | 64 | 18 | 20.0 | 78.3 | 13.0 | 163 | 135 |
| 11,000 | -12 | -24 | 19.2 | 81.4 | 13.2 | 162 | 143 | 24 | -4 | 19.2 | 76.8 | 13.1 | 162 | 137 | 60 | 16 | 19.2 | 76.2 | 12.7 | 161 | 132 |
| 12,000 | -16 | -26 | 18.3 | 79.1 | 13.1 | 161 | 139 | 21 | -6 | 18.3 | 76.6 | 12.7 | 161 | 134 | 56 | 14 | 18.3 | 74.0 | 12.3 | 160 | 125 |
| 13,000 | -19 | -28 | 17.6 | 76.0 | 12.6 | 158 | 135 | 17 | -8 | 17.8 | 73.6 | 12.3 | 158 | 130 | 53 | 12 | 17.6 | 71.1 | 11.9 | 157 | 124 |
| 14,000 | -23 | -31 | 16.8 | 72.9 | 12.1 | 156 | 131 | 13 | -11 | 16.8 | 70.6 | 11.8 | 155 | 125 | 49 | 9 | 16.8 | 68.3 | 11.4 | 153 | 119 |
| 15,000 | -27 | -33 | 16.1 | 70.4 | 11.7 | 153 | 127 | 9 | -13 | 16.1 | 66.2 | 11.4 | 152 | 121 | 45 | 7 | 16.1 | 66.0 | 11.0 | 149 | 114 |
| 16,000 | -30 | -36 | 15.4 | 68.0 | 11.3 | 151 | 123 | 6 | -15 | 15.4 | 65.8 | 11.0 | 149 | 116 | 41 | 5 | 15.4 | 63.8 | 10.6 | 145 | 109 |

*NOTES:*
*1) Full throttle manifold pressure settings are appoximate.*
*2) Shaded area represents operation with full throttle.*

full-rich and at cruise power settings. In fact, detonation testing is the very heart of establishing maximum recommended cruise.

During certification validation, manufacturers must hold the engine free from detonation with a 12 percent margin of safety. This can be found in FAR 33.49 if you wish to review all the hurdles an engine manufacturer must overcome to obtain engine certification.

Additionally, these leaning curves are completed with the engine at maximum parameters, including cylinder head temperature, oil temperature and induction air temperature.

"If you are running your aircraft engine at or below maximum recommended cruise, you can be sure you will operate safely from any effect of detonation no matter what you do with the red knob!"

Setting the parameters to maximum engine limits during these tests reduces the detonation margins and predisposes the engine to more easily experience detonation. Therefore, if you are running your aircraft engine at or below maximum recommended cruise, you can be sure you will operate safely from any effect of detonation no matter what you do with the red knob!

## Air/fuel ratio

Air/Fuel ratio and its role in leaning the measured amount of air and fuel in a combustion process is referred to as the air/fuel ratio (A/FR). Back in high school we learned about stoichiometry in chemistry class. (At least anyone who did not have the captain of the cheerleading squad sitting next to him.) So for me, it was not until I began my flying career that I even knew what stoichiometric mixtures were.

Stoichiometric is a termed used to describe all atoms of air and fuel used up completely during the combustion process. It's about 14.7:1 (14.7 parts of air and 1 part fuel) in the typical aircraft piston engine.

While we may think that is the best possible and most efficient place to operator our engines, the truth is, it isn't.

In fact, most spark ignition aircraft engines produce maximum power slightly rich of stoichiometric. Typically, we can describe a rich mixture as 13:1 and a lean mixture as 15:1. Leaner air/fuel ratios result in higher temperatures as the mixture is combusted up to a point.

## Peak exhaust gas temperature (EGT)

Surprisingly, there are many pilots that do not understand peak exhaust gas temperature (EGT) or how to find it. As stated earlier, a leaner A/FR results in higher temperatures as the mixture is combusted up to a given point and that point is peak EGT.

To find peak we first set cruise power in accordance with our respective POH. Next, we begin to lean while watching the exhaust gas temperature rise. We continue to slowly lean until the EGT stops rising and starts coming down again. That point of change is peak EGT.

This can be found with a single EGT gauge or a multiple point EGT system offered on most engine monitoring systems. Engine manufacturers including Superior Air Parts, Continental Motors and Lycoming do not publish exhaust gas temperature limits.

The reason is the true value of the EGT is not important to the engine manufacturers, as it varies greatly between one engine to another and more importantly, one cylinder to another. EGT can also vary due to altitude and atmospheric conditions.

There are many factors that contribute to EGT readings such as placement of the probe in the exhaust, atmospheric conditions, altitude and power settings. Our only real benefits from the EGT readings are actually knowing where does the cylinder peak and how far are we operating from that peak setting?

The EGT reading is not an indicator of internal stress on the engine. Actually, the EGT is taken downstream of the combustion chamber and a cyclic reading during the exhaust cycle and therefore when the engine is under little stress.

If your aircraft is equipped with a turbocharger, you may have turbine inlet temperature (TIT) limits that are predicated on turbocharger limitations. In these instances, you will typically lean until you find peak TIT. However, always read the POH and know the specific TIT limits for your aircraft prior to leaning!

## Which power is "Best Power?" And how to find it…

On most aircraft, best power mixtures are found on the rich side of peak EGT and slightly rich of stoichiometric. Depending on the engine model, it is usually found somewhere between 75 and 125 degrees rich of peak EGT. You will need to consult your POH or engine manufacturer instructions to determine where best power is developed for your particular engine.

Best power mixture settings will result in the most twist on the crankshaft and the highest indicated airspeed. I hear pilots say all the time that running best power will shorten the life of the engine and the pressures developed will destroy the cylinders. In all my years owning, flying and maintaining piston engine aircraft I have never seen any credible evidence to support those claims.

In fact, I have seen many engineering reports that state the opposite. As we discuss engine management in more detail, combustion pressure and temperature are not four-letter-words. In fact, your engine's manufacturer has tested the engine for durability at this precise mixture setting.

Going back to my charter pilot days, we most always flew best power and routinely ran engines to TBO and in many cases beyond.

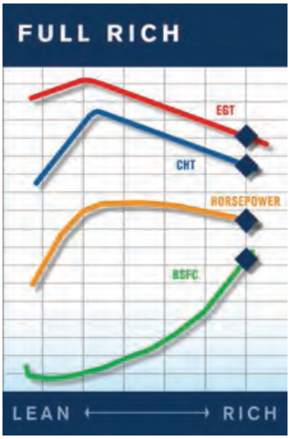
In order to accurately find best power in an engine equipped with a multiple point EGT, you must lean the engine to peak and note which cylinder is the first to peak. That is now

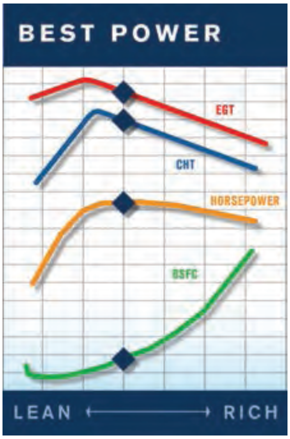
"In order to accurately find the best power in an engine equipped with a multiple point EGT, you must lean the engine to peak and note which cylinder is the first to peak."

the reference point to mark. Once you have that, you then richen the mixture until the first cylinder peaks between 75 and 125 degrees rich of peak (or whatever your POH specifies for best power).

If your aircraft is equipped with a single EGT gauge, the correct method is to find peak and then richen the mixture to the temperature specified in your POH.

Best power will get you wherever you are going the fastest way possible. That is why most of us purchased airplanes, so we can get to our destination quickly. Sure you may burn a little more fuel but you will be in the air less total time.




You can refer to these full rich and best power charts in order to visualize graphically what is occurring in the engine when operating in either of these regimes. In the best power chart, notice the EGT and CHT values have risen from the full rich chart. Horsepower is at the top of the curve and the engine has become more efficient from full rich by the movement of our point to a lower Brake Specific Fuel Consumption (BSFC) number. I will discuss what the BSFC really means a little later in this chapter. For now, the lower we are on the curve, the more efficient the engine has become as a function of mixture setting!

## Understanding lean of peak operations

I am often asked at seminars, fly-ins and other events what I think about this new lean of peak thing? First off, the operation of an aircraft engine on the lean side of peak exhaust gas temperature has been going on just about since the invention of the reciprocating piston airplane engine itself.

So, to me the process is nothing new or innovative.

However, I believe the topic is seeing more attention these days due to the ever-rising cost of fuel and total operational expenses that go along with owning an aircraft. We aircraft owners are consistently evaluating areas for which we may cut some operational costs. I know my wife is the ringleader of this worldwide effort!

On most aircraft engines, best economy is found on the lean side of peak. However, as stated earlier, you must refer to your respective POH or engine manufacturer's data to determine best economy mixture settings for your aircraft. There are many aircraft in which best economy is found at peak.

If your aircraft's best economy mixture setting is lean of peak, then you should set cruise power at or below maximum

"We aircraft owners are consistently evaluating areas for which we may cut some operational costs. I know my wife is the ringleader of this worldwide effort."

recommended cruise and lean until you see the last cylinder peak. The last cylinder to peak is your benchmark or reference point from peak. In most general aviation piston engines, this best economy setting is somewhere between 25 and 75 degrees lean of peak. Therefore, you would lean to the last cylinder peaks and then lean further until that cylinder exhaust gas temperature drops another 25 to 75 degrees.

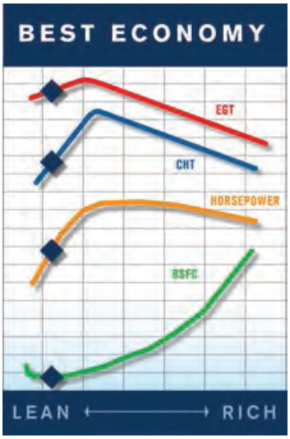
Whenever you are leaning your engine do not get caught in the percent/power debacle. Power should be set at MRC before you begin the leaning process. If you are on the lean side of peak, you may see a drop in percent/power and that is okay.

Additionally, remember that you should never try to compensate for this slight drop with the throttle. Consequently, in best power settings (rich of peak) you may notice an increase in percent/power or airspeed. That's okay too.

Just leave the throttle where it was set to establish your setting at or below MRC. Keep in mind that in many instances the setting may be at a wide-open throttle at altitude for normally aspirated engines.

If your aircraft is only equipped with a single point EGT gauge, you normally would lean to peak and continue to lean until the gauge reads 75 to a 100 degrees lean of peak. In most cases involving general aviation piston engines, the engine should run smooth in a best power or best economy setting and cylinder head temperatures remain less than 400 degrees Fahrenheit.

Refer to the chart on the right regarding Best Economy settings. Notice the EGT and CHT values have dropped dramatically. Also, horsepower has dropped as well so we would expect the aircraft to lose some airspeed. However, we are now at the bottom on the BSFC curve and operating the engine in the most efficient manner.




This all seems simple right? Let's further look at leaning, as I stated earlier, with regard to maximum efficiency and durability. In order to expand on this we need to ensure we clearly understand what BSFC really is.

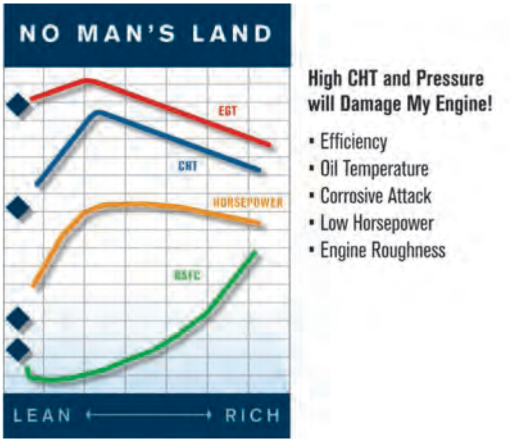
## Understanding Brake Specific Fuel Consumption

Brake Specific Fuel Consumption (BSFC) is defined as, "The rate of fuel being consumed divided by the power being produced." Or in English: How much energy is produced for a given amount of fuel spent. An example would be a 200 horsepower engine that consumes 100 pounds of fuel per hour has a BSFC of 0.5.

Additionally, if the same engine consumed 150 pounds of fuel per hour it would have a BFSC of .75. Therefore, the lower the BSFC number, the more efficient the engine is in terms of turning fuel into power.

Understanding BFSC is key to determining the maximum efficiency of our engines. You may hear owners proclaim a very low-gallons-per-hour (GPH) used during flight, but are they actually operating at the lowest possible BSFC?

As you will note from the chart below, labeled as "No Man's Land," when we lean past the lowest point on the graph, our engines become grossly inefficient and the curve almost goes straight up. Sure we can burn less fuel, but the engine is not producing much power and efficiency has suffered.




## The devil at 380 degrees

So, you ask, "How should I operate my engine in order to achieve maximum efficiency and durability?"

That's a good question. I find that as I talk to owners and read articles written by "industry experts," who are neither an engine manufacturer nor a qualified engineer, there is a great obsession with cylinder head temperature. We have all read articles that proclaim that if any cylinder head temperature gets to or above 380 degrees (F) the world (or at least the engine), as we know it will cease to exist.

We have heard that a demon lives at 380 degrees and will sprinkle "monkey dust" on your cylinders rendering them inoperative. The argument is that the strength of aluminium starts to fade at 380 degrees.

And, while that is true for some materials, it's not the case with modern aircraft cylinders. As you may well expect, piston engine manufacturers take into account the strength and properties of all the metals they are using when designing engine components.

I have reviewed the engineering reports on studies completed on cylinder durability and I can tell you that the limits set forth by the manufacturers are not picked at random. Now I do not for a

"So, in fact, they are managing their engine based solely on cylinder head temperature. That's just wrong."

minute advocate operating your engine at maximum limits and the optimum area is actually something less than 400 degrees.

The problem is the obsession with the number 380! Owners continually tell me they try to keep cylinder head temperatures less than 350, less than 320, all the way down to less than 300 degrees. And they do this by regulating the mixture control. So, in fact, they are managing their engine based solely on cylinder head temperature. That's just wrong.

There is nowhere in the operations manuals that I am aware of that bases engine management purely on cylinder head temperatures. And here is where the problem begins.

When an owner tells me about these very low cylinder head temperatures, the first thing I ask them is, “What is your oil temperature?”

“It’s ok,” is their usual reply. “It’s okay,” is not an answer. “What is the actual oil temperature?” I ask again. “I don’t know,” is their answer. It’s not hard to find. Look at readout on the engine monitor that you purchased to protect the engine. In most instances I find it to be around 130 degrees.

Engine manufacturers and oil refiners all agree, the temperature must be maintained at least 180 degrees to boil off the water and combustion by-products that make their way into our engines. Doing this helps reduce corrosive attack inside the engine.

At these low temperature settings the cylinder head temperatures can be so cool as to cause damage to valves due to the inability to completely burn off combustion deposits. You may also experience a rough running engine. Something I know my wife doesn’t like!

When you obsess about lower temperatures, what you are actually doing is taking energy away from the engine. And we all know that is a very inefficient way to operate any piston engine. If you look back at the No Man’s Land chart, you can see that type of operation leads directly to inefficiency.

## The last word on CHTs

Next, the question of cylinder head temperatures (CHTs) comes into play, especially if you are operating your engine outside of the airframe and engine manufacturer recommendations. We’ve already established that if we operate our engines at or below maximum recommended cruise power, we are protected from detonation and the engine is tested for durability.

If you choose to operate above maximum recommended cruise, detonation margins are reduced. And that margin is reduced even further when cylinder head temperature rises. You can operate safely at power settings above maximum recommended cruise, but you need to understand fully that detonation margins could be reduced.

## A master's degree in engine management

Yes, it can be very confusing. If you really want to dive deep into engine management I recommend attending an Advanced Pilot Seminar in Ada, Oklahoma. These folks offer both online training and actual classroom training sessions.

The classes are taught by George Braly, John Deakin and Walter Atkinson. These gentlemen can help you fully understand engine leaning better than anyone I know of. When I attended the class, I learned a great deal about engine management. In fact, I felt it was so beneficial that I have since sent my entire technical support team to the class.

However, having worked for engine OEMs for most of my aviation career, I am a card-carrying proponent of operations in accordance with all manufacturers recommendations.

If you follow their guidelines for operations and maintenance you are ensured that your engine will perform to the durability limits it was tested for, while staying away from any effects of detonation. This will lead to enhanced safety, reduced life cycle costs and improved reliability – and, of course, much lower ownership costs.

# Using your oil change as a diagnostic tool.

We should not take for granted the information we learn about the health of our aircraft piston engine through a proper oil change. The trick here is really understanding what is "normal" and what is "abnormal." Additionally, oil is the lifeblood of our engines and selecting the right grade and type is critically important.

## What type is the right type?

Aircraft owners all seem to have an innate desire to be kind to their aircraft engines and, in return, they expect their engine will be kind to them. And that means making it to TBO.

One of the most popular questions that I receive from owners is: "What type of oil should I run in my engine?" Not only the specific weight, but also what brand? I joke with owners that no oil company has jumped up and given me a kickback to recommend their specific brand, even though the cost of my daughter's college tuition continues to rise and I could use the extra cash.

In all seriousness, there are many brands available that meet or exceed the engine manufacturer's recommendations. Straight weight oils and multi-viscosity oils certainly have their respective place depending upon the climate you typically operate in.

In order to fully understand the oil recommendations for your engine you should consult your respective engine manufacturer or if you fly a Continental, Lycoming or Superior Air Parts engine, the latest revision of the following documents:

- Continental - Service Information Letter (SIL)99-2
- Lycoming – Service Information (SI)1014
- Superior Air Parts – Respective Engine Operations Manual

These documents list all the approved lubricants for your engine.

In addition, many of the major aviation oil companies publish informational booklets on their products that cover many of the questions that owners usually ask. For example, Aeroshell produces a booklet called the *Answer Book* that contains a huge amount of useful information about aviation oils. If you really want to impress your friends, read it and be able to reference chapter and verse directly from the manufacturer.

## Oil and water don't mix

Unless it is specified by the engine's manufacturer, the typical intervals for oil change for engines equipped with an oil screen is 25 hours and intervals for those equipped with an oil filter is 50 hours. No matter what, at no time should you exceed six (6) months between oil changes.

"No matter what, at no time should you exceed six (6) months between oil changes."

As you know, oil changes are very important to remove the majority of combustion by-products from the oil. But what few aircraft owners realize is that your aircraft engine produces about the same amount of water as they consume in fuel. So if an engine is consuming 10 gallons of fuel per hour, it is producing about 10 gallons of water.

Most of the water goes out the exhaust in the form of vapor, but some gets by the rings and becomes trapped in the oil. That is why oil temperature is key in preventing corrosive attacks and premature cam/lifter spalling.

In every instance of cam lifter spalling that I have seen the damaged parts met or exceeded metallurgical requirements, but were damaged by corrosion pitting, which could have started by moisture build up in the oil.

If you want to be really kind to your engine, change your oil frequently and ensure that the operating temperature of the oil is at least 180 degrees F. Again, follow engine manufacturer's recommendations in concert with those of your respective oil manufacturer.

## How much is too much?

Another thing you should do is continuously monitor oil consumption rates. A change in consumption may be a clue to a pending problem. I keep a little oil use log in my personal aircraft so I can keep track of when oil was added and the time intervals between those additions.

This type of detailed information can be very useful to your maintenance provider when it comes time for annual inspection or when diagnosing engine issues. Oil consumption is normal in our aircraft piston engines. Normal oil consumption ensures lubrication of the cylinder walls and adequate piston and ring cooling. But, I am often asked: "What is abnormal oil consumption?"

That's a difficult question to answer without having lots of details. I usually answer the question with, “If you have to stop for oil before you stop for gas, you may have a problem.” As funny as that may sound, in most cases, it’s not far from the truth.

“If you have to stop for oil before you stop for gas, you may have a problem.”

As a starting point, there is a formula in your Engine Operations Manual that you can use to calculate maximum brake-specific oil consumption. The number is based on percent power and in most cases works out to be close to one (1) quart every hour.

The maximum brake-specific oil consumption number is actually derived from engine certification. The engine manufacturer must demonstrate the engine/airframe combination will run out of fuel before running out of oil. This is often where sump capacity is derived and the very reason many of our aircraft will blow the top one or two quarts of oil out very quickly.

During certification, manufacturers have to show that with the sump filled to capacity and the engine consuming maximum amount of oil allowed, there is no danger in exhausting the engine of oil before fuel.

With regards to “abnormal oil use,” the problem is that similar model engines can consume oil at very different rates based on their age, usage, percent power flown, operating conditions and the environment in which it is operated.

The best first step is to know how much oil your engine should be using under normal conditions, and then monitor exactly how much oil your particular engine is using. If it’s more than the book says, consult with your mechanic or your engine manufacturer.

Additionally, just because there is a change in oil consumption does not necessarily mean the engine requires a top overhaul. Change in oil consumption can be something as simple as a filler cap not fitting properly, leaking nose seal or orientation of the engine breather system. You should ensure your maintenance provider has checked all variables before engaging in a complete top overhaul.

## The right way to inspect an oil filter

Your filter can tell you a lot about the health of your engine so always make sure that you or your maintenance provider cuts the oil filter after removal and inspects the pleats. Oil filter cutting tools are not very expensive and are available from most any aircraft tool supplier.

Notice I said cut after removal. There has been a practice of punching holes in filters prior to removal in order to drain the oil from the filter before removing it from the engine. While it may cut down on the mess, it can cause real problems.

By punching holes in the filter, there is real danger in introducing filter material into the inlet of the oil pump. I have examined many engines in which this practice resulted in starter adapter damage and in some cases catastrophic engine failure.

"I know, I know, but Bill, I don't hit it very hard," the owner might say.


*Oil filter cutting tools remove the case without introducing metal into the filter.*

My response to that would be: "Show me the calibration sticker for your arm." Simply, the best practice is not to do it.

Tempest, and other companies, have developed a tool that will safely remove oil from the filter prior to removal without introducing foreign materials. If you don't have the special tool, another method is to put a large freezer bag over the filter during removal. The bag will catch most of the oil.

Now, once you've correctly cut it open, it's not uncommon to find some metal in the oil filter. We certainly don't want to find pieces large enough to read part numbers. Each engine wears material at a little different rate and what we are inspecting for is a relative change in the amount of that material over time.

If you have an "abnormal filter" – a filter with an unusual amount of metal or containments – most engine manufacturers will allow the filter be sent to their facility for a more thorough examination. Superior Air Parts provides this service to its customers at no charge.

*Inspect the filter pleats for metal particles and other materials.*

The first thing most engine manufacturers will do is to examine the contents under magnification. In order to do this, the technician will wash the contents of the filter into a clean Petri dish. The constituents of the filter will be rinsed in the dish several times using acetone or another suitable clean solvent. This exercise will remove much of the oil and carbon in the sample, both of which can distort the examination.

Under magnification, the trained and experienced technician can determine the type of material and its possible origin. If they

"Oil analysis should never be used as a snapshot in determining the internal engine health."

are unable to make a determination under magnification, the technician may choose to pass the sample to the staff metallurgist for proper identification. Metallurgists can utilize a scanning electron microscope and specialized chemicals to determine specific material type and origin.

## Consistency is key to good results

It is a good practice to have your engine on an oil analysis program. Obviously, the analysis data is used to show spikes or relative change over time. However, in order for an oil analysis to be effective and provide meaningful data, the analysis must be completed over time. Samples should be taken from the engine at the same hour-intervals and submitted to the same laboratory for examination.

Oil analysis should never be used as a snapshot in determining internal engine health. I have had aircraft owners and mechanics contact me and tell me they are thinking about purchasing an aircraft that has been sitting for several years and want to know if I think they should have an oil analysis?

Honestly, the information provided in this test is not going to be very useful. Without even seeing the aircraft or engine, I can

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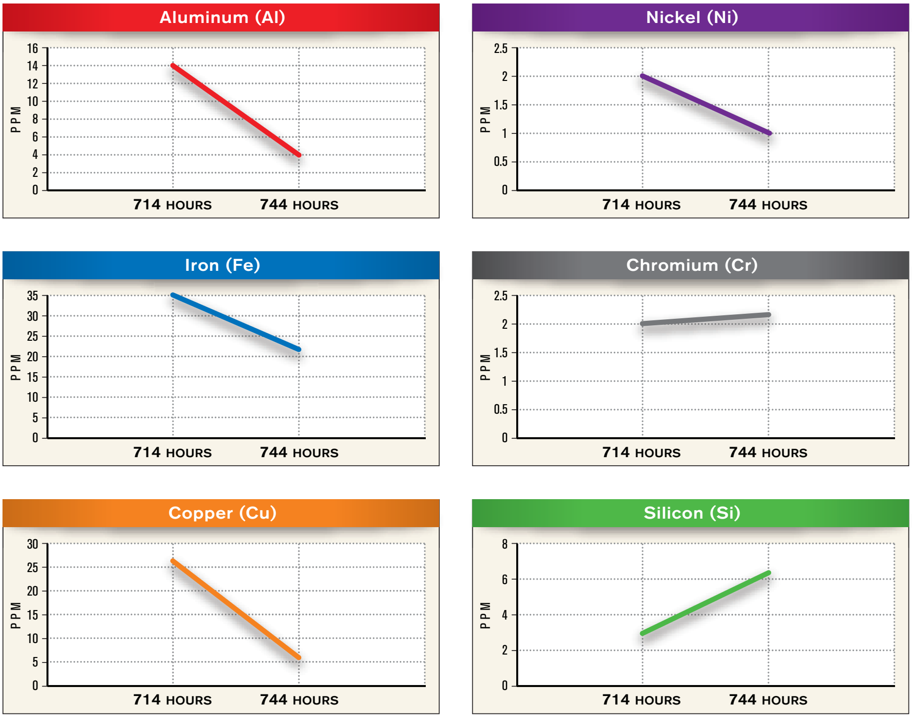


*Use routine oil analysis to help spot any abnormal trends before they lead to major issues.*

guess that iron will be off the chart due to corrosion. There are other inspections and tests that can be performed on an engine that has been sedentary for a long time. These include borescope and partial disassembly inspections that can be very useful in determining if the engine has damage from being inactive.

Also, the oil analysis is usually given in a parts-per-million unit of measure. I have had customers that get very excited when the iron level goes from 54 parts-per-million to 74 parts-per-million. Years ago, I had an owner contact me with a 20 parts-per-million change in iron and demanded a new engine.

Now lets see, if we filled a room with a million ping-pong balls and painted 74 of them red, could we find them? Probably not. My point here is that it is a very, very small amount of material.

"Years ago, I had an owner contact me with a 20 parts-per-million change in iron and demanded a new engine."

What we are really looking for is a large spike in wear levels as tracked over time. Reputable oil analysis companies provide universal averages, but it may be very normal for your engine to wear slightly outside these values.

This does not constitute a problem with your engine or that your engine will not make it to TBO and beyond. Some of the oil analysis companies find it necessary to make comments on the values. That being said, if the values in your analysis report seem abnormal to you or your mechanic you should immediately consult your engine manufacturer.

## What about oil additives?

Right after answering the, "What kind of oil?" question, the typical owner then asks for my thoughts on the variety of oil additives that are available today.

I have a confession to make to you: working for engine manufacturers for the better part of my career, there always seemed to be a "snake oil" sales person that wanted to speak with me about their latest product. They wanted to show me how the engine could continue to operate with no oil pressure and still function normally. For years I dismissed these claims and gave these folks little, if any, of my time.

Then it all changed. One day at Oshkosh, I overheard a technical representative for the engine manufacturer I was working for talking with one of our customers. The aircraft owner asked about CamGuard and the technical representative replied: “Snake oil. Don’t use it.”

After hearing the words come out of his mouth, I began to reflect on some of my own opinions of additives in the past. He and I were making a rash judgement on a product with no technical information to back our opinions up. I realized that was just not professional.

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“After hearing the words come out of his mouth, I began to reflect on some of my opinions of additives in the past.”

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So, at the end of their conversation, I called the representative over and asked him: “How do you know it is snake oil? Have you tested it?” His answer was no. I told him in no uncertain terms that he should have explained to the customer that we cannot approve the additive simply because we as the engine’s manufacturer have not tested it.

The next thing I did was contact the CamGuard technical representatives and requested a meeting. I discussed with them how the testing of their product was cost prohibitive for the manufacturer but wanted to see if we could test in another manner. The first item we needed to determine was that the introduction of the product into any engine could not lead to any harm. There was no evidence that it would cause any harm.

Next, after having studied the engineering data and reviewing it with our engineering department, I decided we would engage in a lengthy study of the product on overhauled engines from our service center. To do that, we developed a program where we could analyze the use of CamGuard on 25 engines to determine what, if any positive effects it had on the engines' wear components.

Unfortunately, while initial tests were positive, I left the company before the test was concluded.

It did however convince me enough that I have used it in my personal aircraft for years and have noticed improvement in wear material levels.

As to whether you should use an additive like CamGuard, it's up to you. But before you make any decisions, I strongly urge you to consult with both the manufacturers of CamGuard and the manufacturer of your engine for specific recommendations.


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# Cylinder compression testing.

***A note from Bill:***
*As you read through this section, it will probably conflict with a lot of what you have been taught, told or read over the years about cylinder compression testing. But, rest assured that everything contained within is based on manufacturer's recommendations and absent of any personal opinions.*

The popular design of the cylinder found on today's aircraft piston engine was actually co-developed back in 1918 by A. H. Gibson and Sam Heron in Farnborough, England.

The steel barrel threaded into an aluminum head allows for very dense cooling fins and large ports due to the lack of cylinder head bolts. It proved so efficient that the Gibson-Heron design was adopted by leading aircraft engine manufacturers such as Pratt and Whitney and Curtis Wright, and virtually every other maker of air-cooled aircraft engines since.

Obviously, their design has proven to be very durable. And even though there have been refinements over the years the basic design hasn't changed in over a century.

But, while the cylinder's design hasn't changed, materials and metal alloys have. When a cylinder is designed and manufactured the strength of material is always a key engineering consideration. Materials used to manufacture aircraft engine cylinders must undergo very rigorous metallurgical and pressure testing to prove they can withstand the stresses built up during compression.

## Performance under pressure

We all tend to rate an engine's health based on the compression reading of its cylinders. The rule of thumb followed by many an owner and mechanic is the higher the compression reading, the better the engine. Ah, if engines, and life, were only that simple.

The truth is, that rule is not necessarily the accurate indicator we want it to be. In fact, I have inspected engines with very good compression readings that also had full-faced lifter spalling and camshaft distress. Both of which are signs of significant damage.

"I have inspected engines with very good compression readings that also had full-faced lifter spalling and camshaft distress."

"Good compression numbers" have led more than one aircraft buyer down a false path during a pre-buy inspection, resulting in considerable financial outlay after just a few hours of operation.

So what is the purpose of a compression test and what does it really tell us? Lets think about what the compression test is before we answer that question. To perform the test, we pump 80 pounds of shop air into a cylinder and read the leak. However, 80 pounds of air is in no way representative of what is actually occurring in the cylinder under the dynamics of combustion.

When operating at normal power, a "healthy" cylinder actually has internal pressures of close to 1,000 psi. These pressures are not detrimental to the cylinder, but actually help seat rings and close valves tightly, helping create the seal. So, in reality, all we are doing with a compression test is identifying the leak source at 80 psi and not really the overall health of the cylinder or engine.

In most cases, the leak is usually identified at one of two potential sources: The rings, which can be evident of air discharge through the engine breather tube, or the valves, which can be evident of air discharge through the intake or exhaust.

## Follow the instructions

There are several factors that can affect compression readings such as ring gap, bore size, ring design, and operator technique. Manufacturers have developed specific instructions for conducting compression tests in order to minimize the effects of these variables.

Continental and Lycoming have published Service Bulletins that you should make sure your maintenance provider has and is following when performing compression tests. If you will take the time to speak with your mechanic and review the documents, it will likely save you money, time and trouble. Plus, it will also improve your engine's safety.

- Continental Engines Service Bulletin SB03-3
- Lycoming Engines Service Bulletin 1191

Each of these documents is available at the respective engine manufacturer's website and you should ensure you always use the latest revision available.

I strongly urge you to print the latest directions pertaining to your engine and take a moment to review with your mechanic. If your mechanic has not heard of these documents, you may wish to find another mechanic (see Chapter 1). However, if the mechanic happens to be your brother-in-law, in the interest of family harmony, you may want to send him to one of the manufacturer's engine maintenance schools. I actually encourage mechanics and pilots to attend this training together. I refer to this as "couple's therapy."

In all seriousness, it will certainly improve communication between you and your mechanic. While the classes are designed for the advanced technician, they are very useful to owners and the information can get you both to ask the right questions.

## Compression testing 101

Both of these documents standardize operator procedures, including the correct equipment and settings to use for compression testing. Even compressor output, hose size and compression testers are all placed on an even playing field. Additionally, these factory procedures will allow for differences in compression readings caused by variations in piston and ring design.

Each document requires the mechanic to use a compression tester that incorporates a Master Orifice Tool. (The orifice tool is what is by the manufacturer to determine the acceptable leak limit in each cylinder.) One of the most common testers is the Eastern Technologies E2M which has the master orifice built in to the unit.

The tool is used to establish the leak limit prior to the compression test and that is the only use of the tool. Prior to the compression test, the technician will connect the tester to shop air and set the regulator for 80 psi on the left side gauge. Then the technician will set the left hand lever to "Pressurize."


The Master Orifice or right hand lever is then moved to the test position and we read the leak limit on the right hand gauge. The number observed is the minimum allowable compression reading for each cylinder. Once this test has been completed, the technician will record the leak limit. The mechanic is now ready to perform the compression test on each respective cylinder.

In most instances, my E2M will have a leak limit of around 39 to 45 psi depending upon atmospheric conditions. But wait, you ask: "How can that be?" Certainly you have heard that if compressions fall below 60 psi that the world as we know it will cease to exist and the sky will fall. That's what the "experts" tell you anyway.

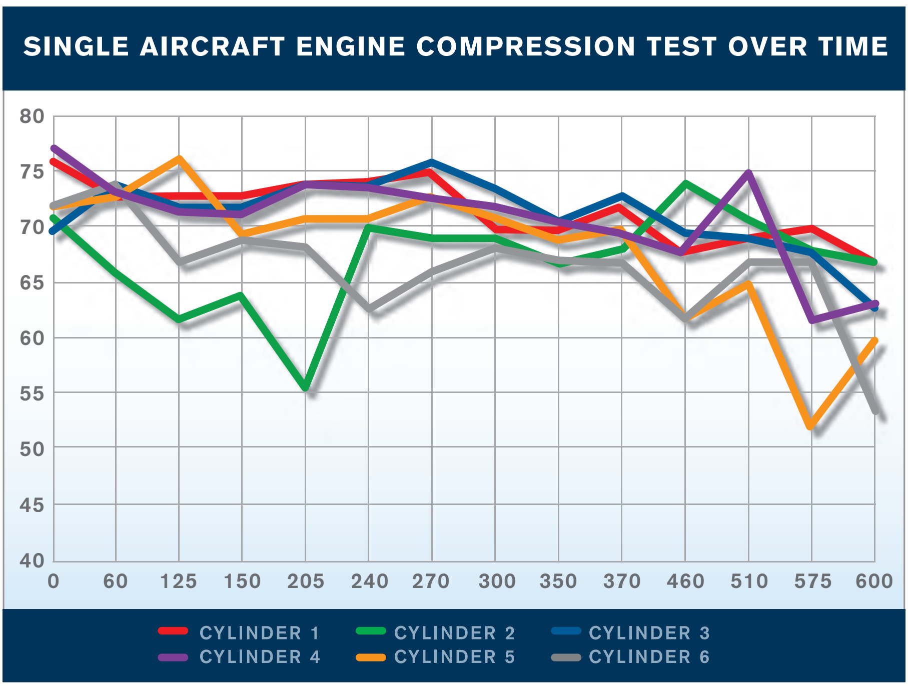
Where did that type of thinking come from? You should note that engine manufacturers have done a lot of testing with compressions near zero with very little change in engine horsepower or torque output.

Remember, the 80 psi we squirt in the cylinder is in no way representative of what is occurring in the cylinder under engine operation.

## 80 isn't what it used to be

So how did we as an industry arrive a 60/80 psi as the overall benchmark for engine health? This actually came from the FAA Advisory Circler (AC) 43.13, Chapter 8, which is a guide for "acceptable methods, techniques and practices for aircraft inspection and repair."

This AC states that in the absence of manufacturer instructions, "Thou shalt use 60 psi!" Today, we have manufacturer's instructions and 60 psi is no longer the magic number. We also



"The average mechanic that is not familiar with the Service Bulletins would have probably pulled the cylinder at 205 hours and replace it costing the owner thousands of dollars in unecessary repairs."

know that target compressions are cyclical and change over time.

For example, in the test performed on the engine shown in the chart on page 60, the compressions varied over time. The average mechanic that is not familiar with the Service Bulletins would have probably pulled the cylinder at 205 hours and replaced it costing the owner thousands of dollars in unnecessary repairs. All without adding one bit of added safety to the equation.

Think about this for a moment: If the engine manufacturers really did not have your best interest in mind, would they publish a document that would allow compressions to fall below the 60 psi mark? Of course not.

"If the engine manufacturers really did not have your best interest in mind, would they publish a document that would allow compressions to fall below the 60 psi mark?"

If this were the case, think about the number of cylinders that they could actually sell. The unfortunate part of this is that I speak with owners and mechanics each day that are not familiar with these Service Bulletins and, because of that, are needlessly changing cylinders – a mistake that is costing them lots of time and money – all because the compression dropped below 60 psi!

## Let's look inside

When performing comprehensive cylinder compression testing, there is a requirement for a borescope inspection. This is the most meaningful portion of the complete test because it provides immediate representation of the internal condition of the cylinder. Items that we look for are scuffing or scoring signatures on the bore along with the condition of the cross hatching hone pattern and for any indications of a transfer of metal.

We can also look for oil pooling and combustion deposits, which are great indicators of how the cylinder is functioning. In fact, based on the amount of combustion deposits I can easily determine if the pilot operates lean of peak, rich of peak, or if he even knows what the red knob is for!

In addition, the condition of the valves is key in making a determination of overall cylinder health and functioning. We can easily determine if a valve is becoming burned and if it is dissipating the heat properly in to the head. Looking at the pictures below we can actually see a normal valve and its progression to failure.

In the normal valve, there is a definitive concentric ring of heat dissipation. Do not get caught up in the color, look at the concentric ring. In the "starting to burn" example photo, the valve no longer exhibits a concentric ring of heat transfer. The heat is

*What a nearly new valve looks like through a boroscope*

*Normal looking valve*

*Valve starting to show signs of burning*

*Burnt valve*

*Burnt and failed valve*


*Damaged valve seat as seen though a video borescope.*

now becoming concentrated in a small area. The burned valve has a very concentrated area of heat transfer and if left in service will likely result in failure.

Many mechanics and owners think the only way to burn a valve is to operate the engine too lean or too hot. I have heard folks say, “He burned a valve running lean of peak.” That is absolutely not true! On the lean side of peak exhaust gases are cooler and combustion pressure lower.

In fact, you can actually burn a valve by operating the engine too rich. How can that be you might ask? If the engine is operated too rich, the cylinder remains very cool so the lead and combustion by-products cannot get burned or melted away.

These residual deposits can attach themselves to the valve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> "You are not doing the engine or cylinder components any favors by operating it very cool whether you chose rich or lean of peak settings."

and in some cases under the valve holding it slightly open during the power stroke. This can provide a path for hot gas to escape through the opening and burn the valve much like a torch you find in a workshop. The hot gases can also make their way up the stem of the valve and damage the guide.

Think back to our discussion regarding engine management, the manufacturer recommends certain power settings and cylinder head temperature ranges that are predicated on good cylinder component function. You are not doing the engine or cylinder components any favors by operating it very cool whether you chose rich or lean of peak settings.

## Scoping out borescopes

As for borescopes, they are becoming much better and much less expensive. There are borescopes on the market today that are in the $300 range that have fairly good optics and have photographic capabilities.

I talk with maintenance providers each and every week that do not own a borescope, yet they are maintaining aircraft. How can that be when a borescope inspection is required in making an airworthiness determination of cylinders? You, as an owner, should ask if your current mechanic owns a borescope or not.

If the answer is no, there is a good chance he or she is not inspecting your aircraft engine in accordance with the manufacturer's instructions. If you want to be kind to the mechanic (and your engine), you may wish to fill his or her Christmas stocking with a borescope. The informed and well-equipped mechanic will save you money in the long run.

"If you want to be kind to the mechanic (and your engine), you may wish to fill his or her Christmas stocking with a borescope."

The borescope I use and that is recommended by Continental Motors in the compression testing SB is a Lenox Autoscope. It's not very sophisticated, but it still delivers very good optics for cylinder inspections.

## What can your oil color tell you?

The oil color can be another very good indicator of cylinder health. If after you change the oil it becomes very dark, very quickly (just a few hours), the cause is, quite likely, what we refer to as "blow-by" getting past the cylinders.

Blow-by is a situation where the combustion gases are not being sealed by the cylinder rings and an abnormal amount of these corrosive gases are escaping out past the rings. Many times, excessive blow-by can be characterized by higher than normal oil temperatures. The reason for this is the hot gases make their way to the oil much quicker and can superheat the oil past engine limitations.

Due to the escape of the combustion deposits into the oil, the oil becomes black as tar in a very short period of time. Because of this, the oil color should be inspected each time the oil is checked. With experience, you can certainly determine what color the normal or abnormal oil is in your engine.

Normal oil color signatures for aviation oils are a gray to dark gray appearance as the oil captures and holds the carbon and other combustion by-products in suspension.

Another indicator of excessive combustion blow-by is an abnormal discharge of oil through the engine breather. As the blow-by amount increases, the internal crankcase pressure increases to a point were these excessive pressures must vent. During this venting process, a large amount of oil can be carried out through the breather.

The signature of this situation is high oil consumption accompanied by a large amount of oil discharge on the belly of the aircraft. Of course, it is important to note that an engine could have high crankcase pressure and discharge of oil through the breather without combustion gas escaping past the rings.

Other causes for oil discharge through the breather could be a leaking crankshaft nose seal. The ram air pressurizes the crankcase forcing the oil out. The oil filler cap seal may be worn or not functioning properly causing engine nacelle pressure to enter the crankcase and discharge out through the breather. Aircraft

> "As the owner/operator of an aircraft, you should use this chapter's items in collaboration with your maintenance provider to assess and maintain good cylinder health."

engine manufactures publish instructions on how a mechanic can accurately measure crankcase pressure. For example, Continental Motors published SB M89-9, which explains how this test is accomplished by plumbing an airspeed indicator into the oil filler and reading the indicated airspeed.

The bulletin incorporates a conversion chart from indicated airspeed to inches of water with specifications for normal and abnormal readings. Obviously, a mechanic who is familiar with this type of test should only perform the inspection.

As the owner/operator of an aircraft, you should use this chapter’s items in collaboration with your maintenance provider to assess and maintain good cylinder health. Remember from previous chapters; following manufacturer’s recommendations and using qualified experienced mechanics to maintain your aircraft engine will lead to enhanced safety, reliability and reduce unnecessary repairs to your aircraft.

# "My engine is 50 hours from TBO..."

What does that really mean? Today, there are many proponents in the industry making a case for flying the aircraft until it breaks and not necessarily adhering to manufacturer's recommendations for continued airworthiness. To me, that's just asking for trouble. How do you know when the aircraft will "break?" Will it be on short final at your home airport or at night, in the clouds with your family on board? Is it worth that risk to you? I certainly hope not.

"How do you know when the aircraft will "break?" Will it be on short final at your home airport or at night, in the clouds with your family on board?"

I can remember growing up on the farm, and some in my family subscribed to this way of thinking with their approach to equipment maintenance. However, these wizards also had to keep a towrope, jumper cables, bolts, pins, shafts and starting fluid with them in order to make it through the day.

My dad finally said, "This is crazy," and we started performing the prescribed maintenance recommended by the equipment manufacturers. Eureka! We threw away the starting fluid, jumper cables, towrope and all the other "get-by" items.

These tractors were not new and had been working for many years before we changed our way of doing things. All of the old equipment is still functioning well today. In fact, to this day, neither my father nor I own a set of jumper cables. When batteries approach the end of useful life, they are replaced. Productivity on the farm went way up just due to the reliability of the equipment. We became so efficient, *little Billy* was able to take flying lessons!

My opinion is you can safely fly past TBO without consequences if you and your maintenance provider follow the engine manufacturer's recommendations.

## The ABCs of TBOs

Let's look at what the term time between overhauls (TBOs): The FAA requires the manufacturers to publish a TBO for each of their engines. These aren't numbers that are pulled out of a hat. The engine manufacturers establish these recommendations based on typical maintenance and typical engine operation.

Engines are required to have both an accumulation of actual operating time and calendar time recommendations. Mistakenly, many pilots try to "extend" their engine's overhaul, and cost thereof,

> "Mistakenly, many pilots try to "extend" their engine's overhaul, and cost thereof, by not flying as often as they should."

by not flying as often as they should. The fact is lack of consistent use is probably one of the worst things you can do to an aircraft engine. (Therefore, all of you please contact my wife and ask that I be given a larger Avgas allowance!)

Aircraft engines that are sedentary for many months, and sometimes years, at a time are more likely to have internal damage than those that are maintained and flown regularly. Most engine manufacturer's recommend that if the engine is going to be inactive for six (6) months or longer, it should be preserved in accordance with their respective instructions. Every manufacturer publishes service instructions on how to properly preserve the engine and it does not take a lot of effort.

## TBO: Your time has come

One of the questions I get asked most frequently about TBOs is whether an owner should overhaul or replace their engine? I always reply, "Heck yeah." Followed up by, "My daughter is at the University of Alabama (*Roll Tide*) and tuition is damn expensive. Please, please overhaul your engine and buy our parts!" (That's just sort of the sense of humor I have.)

In all seriousness, the owner and his maintenance provider should ask a few questions in order to make an informed decision.

We need to understand what our options are as when deciding what to do when your engine reaches overhaul time. Basically you have six choices:

1. Purchase a new engine.
2. Purchase a rebuilt engine.
3. Have your engine overhauled.
4. Patch the engine of leaks, low compressions and accessory issues.
5. Wait too long.
6. Do nothing.

Let's explore each option so we can understand exactly the differences and their ramifications.

## OPTION 1: Purchase a new engine

When you purchase a new engine every part is new and meets factory new specifications. Typically you or your mechanic would order the engine from the manufacturer and turn your existing engine in as a core exchange.

Keep in mind, the manufacturer may or may not upcharge you for items missing or worn beyond service limit specifications. The new engine has a new serial number and is zero-time.

In the past, new engines have enhanced aircraft value, but now some of the other options available to owners can often provide equally as much resale value. Often times the new engine comes with a very attractive warranty and that is usually why some owners chose this option.

However, there is really no "technical benefit" to the new engine. It will not necessarily provide you with any more power, smoothness, better performance, or longer service life than any of the other options we will discuss.

"However, there is really no "technical benefit" to the new engine. It will not necessarily provide you with any more power, smoothness, better performance, or longer service life that any other options we will discuss."

## OPTION 2: Purchase a rebuilt engine

Rebuilt engines are different from overhauls. Even though in the industry, people often use the terms interchangeably. The rebuilt engine is assembled at the engine's original manufacturer using various parts from their used/reclaimed stock.

When rebuilding an engine, the manufacturer is not required to disclose the total hours (times) on those "stock" items. Therefore, you could have a crankshaft or crankcase that has a lot of hours or several previous TBO intervals on it.

Nevertheless, rebuilt engine components must meet factory new fit tolerances, but specific parts can be machined undersized to meet specifications.

For example, an engine manufacturer could machine a crankshaft .010 undersized and still assemble the engine with factory tolerances between the bearings. The way to accomplish this is to utilize a thicker bearing which can bring the fit into the desired tolerance. There is nothing inherently wrong with this practice but could result in an unusable crankshaft at the next overhaul. Rebuilt engines are issued new serial numbers and granted zero-time by the manufacturer.

## OPTION 3: Have your engine overhauled

The overhauled engine option is where your original engine is removed from your aircraft and sent to an overhaul facility. Overhauled engines are required to be reworked to service limits only. However, most reputable overhaul facilities are reworking engines to tighter tolerances. The overhauled engine may utilize many of the existing parts that meet specifications. Those that fail are replaced.

Typically, overhauled engines receive new cylinder assemblies, hardware, gaskets, bearings and other piece parts. Historically, an engine overhaul has been the most economical option for aircraft owners. If you fly some of the antique aircraft like my Stearman, it is the only option.

There are many very reputable overhaul facilities worldwide. The majority of these are small shops that specialize in aircraft engine overhauls. Due to the small size of these facilities, overhauled engines are not assembled or worked on a production line but rather given very close attention by one or two engine builders.

The overhauled engine is not granted zero-time status. The engine's total time is continued from the point of overhaul. For example, the engine may have 2,000 hours and zero-time since major overhaul. The engine still has 2,000 hours total time.

The overhauled engine, if worked-up by a reputable individual or facility, enhances aircraft value greatly. In fact, many informed owners regularly prefer the overhaul option to the factory. Why? Simply, because it keeps the engine/airframe serial numbers as matching pairs. That means a lot to some owners.

### OPTION 4: Patch the engine of leaks and low compressions

Patching the engine should be only considered if the internals of the engine are determined to be in good condition. That means no metal in the filter and the oil consumption is within the limits set forth by the manufacturer.

Most aircraft engine failures that I have investigated or have performed analytical inspections after the fact, failed due to either a malfunction in the fuel delivery or ignition system. Therefore, always follow the manufacturer's recommendations for continued airworthiness for items periphery to the engine. These accessories including the magnetos, alternator and fuel delivery system need to be in top condition. Like the engine as a whole, each of these components have specific service intervals that should be followed.

For example, ignition systems typically have 500 hour inspections and some have requirements for overhaul after four (4) years in service or five (5) years from date of manufacture.

Remember that doing a pre-flight run-up and magneto check at the end of the runway is not always an indicator of good ignition system health. Preventative maintenance to these items can go a long way in providing enhanced reliability and safety.

### OPTION 5: Wait too long

One of the airplanes we own had the original engine it was delivered with back in 1966. When we purchased the aircraft it only had about 1,200 hours total time. Many of you might think, wow, it had lots of time left on the engine. Which it did…

But, we were continually repairing oil leaks, reworking accessories and worrying about becoming stranded away from home base. This continued for a number of years until one day I was performing an oil change. I invited my daughter to ride with me around the patch in order to warm the engine oil. We came back, landed and removed the cowling for draining the engine oil.

When the oil began to flow, I noticed what looked like pieces of metal flowing from the drain hose. That's not good. I then pulled the oil screen and we could almost read the part numbers for the metal coming from the engine.

I remember the look on my father's face. It wasn't a look of financial distress but rather relief. Now we had a valid excuse to overhaul the engine. The trouble here is we could have waited too long.

"I remember the look on my father's face. It wasn't a look of financial distress but rather relief. Now we had a valid excuse to overhaul the engine."

Not only was it a risk to our safety to push the envelope on this engine, but also by continuing to fly it, we could have done irreparable damage to the engine that would have been more costly to repair than a standard overhaul.

Luckily, what little internal engine damage we found was easily repaired during the overhaul. Ever since then, the engine has more power, runs cooler and we now are very confident in its reliability. We no longer worry about becoming stranded away from home base.

## OPTION 6: Do nothing

The last option is to do nothing. What I mean by that is by definition, TBO is just a "recommendation." It's not a law. Many engines go beyond TBO and perform very well.

But before going that route, you need to have a thorough evaluation of the engine's current state. Questions that I ask of owners that question me about going beyond an engine's TBO are:

1. What is the calendar time since the engine was new or last overhauled?
2. What is the oil consumption?
3. Do you have any persistent oil leaks?
4. Have you discovered any wear material in the oil during analysis?
5. What is the reliability of the accessories including the magnetos, alternator, carburetor or fuel injection system?
6. What price do you put on your peace-of-mind?
7. What price do you put on the safety of you and your passengers?

While there are plenty more questions I could ask, these few hit the high points when it comes to an engine's overall health or lack thereof.

### What is the calendar time since the engine was new or last overhauled?

Why does that matter? Remember that inactivity of an engine can be very damaging due to internal corrosion. That fact than an engine has low operational hours does not mean a thing to me. For example, look at the ads that list aircraft for sale. I have never once seen an ad that actually stated the engine calendar time.

"Inactivity of an engine can be very damaging."

You see many with 500 or 600 hours since major overhaul or since new all the time. But what buyers should be asking about is, "What is the engine's actual calendar time?" How long has the engine been sedentary? Generally, you would like to see the aircraft flown at least a couple times per month.

**"Oil that is...black gold...Texas tea..."**

Another critical thing that helps determine the overhaul health of an engine is its oil consumption. Does it have any persistent oil leaks? Or have you discovered any wear material in the oil during analysis? Look back at Chapter 3 regarding using oil changes as a diagnostic.

With regards to oil consumption; are you constantly filling the oil everytime you fill up with fuel? If so, your engine is likely a candidate for replacement or overhaul. Increased engine oil consumption could be the result of actual engine usage, leaks or a combination or both.

An old engine that is beginning to show these symptoms is probably getting close to needing overhaul, replacement, or significant repair. The question to ask yourself is: How long can I continue to bale the engine together?

## What price do you put on your peace-of-mind?

Peace-of-mind for you and your passengers is very important. You know when I take folks flying in the Stearman for their first time, they will ask questions like, "How old is this airplane?" and "How long have you been flying?"

"Well," I say in my most reassuring voice, "the airplane turned 76 years old on April 4, 2017 and I have been flying now for about two-weeks." (There's my unique sense-of-humor again…)

You can figure that if the Stearman were equipped with an ejection seat, they would pull the handle to get out right there.

I then put their mind at ease saying that while the aircraft is 75 years old it has not been many years since its full restoration. Not only that, but the aircraft has been updated with safety equipment that was not available in 1941. And then, I let them know I could fly an airplane before I could drive a car and they become very relaxed.

"You can figure that if the Stearman were equipped with an ejection seat, they would pull the handle to get out right there."

Passenger comfort and safety should be our priority and having a nice clean new or overhauled engine for them to view during pre-flight can go a long way in providing that confidence. That can be a lot better than having to tinker with the tired dirty engine, get out the jumper cables and make repairs right before we intend to fly. Our engines should be maintained in a state of readiness.

## To TBO and beyond

I am not advocating that you rigidly adhere to your engine's recommended TBO numbers, but the manufacturer is required to provide one as a point of reference.

Clearly you can safely fly past TBO, provided you follow the manufacturer's recommendations for determining continued airworthiness of the engine. Those owners and maintenance providers that follow the proper maintenance guidelines will beat others to

"Clearly you can safely fly past TBO, provided you follow the manufacturer's recommendations for determining continued airworthiness of the engine."

the engine's TBO numbers and beyond through overall lower operating costs and improved safety.

Basically, if your engine is not producing abnormal wear metal, has good compressions, does not consume oil at an alarming rate and is maintained in accordance with manufacturer's instructions, more times than not you can safely fly past TBO without any issues. And there are folks who do it day in and day out.

Look back at the example of my dad and his approach to farm equipment maintenance. I failed to mention, he drove a Chevrolet Chevette (considered to be a disposable automobile) to nearly 300,000 miles without any major issues. When the car was sold, it ran as well as the day he bought it!

My point here is that you can expect long life out of your aircraft's engine if you take care of it and do what the maintenance and inspections when and how the manufacturer recommends.

## Don't get the blueprint blues

Over the years, I have seen many owners spend countless amounts of money on balancing and blueprinting their engines. In theory, these expenditures are an attempt by the owners to have the smoothest, safest and most powerful engine possible.

The sad thing is that while these owners are spending big money on these types of "improvements," they are, in many instances, sacrificing the proper care and feeding for the engine.

Let's fact it: Most of these performance modifications result in no significant gains with regards to operational smoothness or performance. Our aircraft engines are not Formula 1 race engines that turn at 20,000 RPM, but rather operate at 2,700 or 2,800 RPM max. In fact, if you discuss the topic with knowledgeable aviation engineers they will advise you it is a waste of money.

## Make the smooth connection

The number one thing that will provide for a smoother running engine has nothing to do with the engine's design or assembly. It's as simple as ensuring you have the correct engine-to-airframe installation. Many of the vibration complaints that I have worked over the years were actually not the engine but rather a poor installation.

Precisely following the proper techniques and practices during installation results in the engine being correctly isolated from the airframe, thus keeping vibration at a minimum.

I can remember many years ago when I was working for another engine manufacturer, a customer called our technical support line to report bad vibration. The owner and his mechanic went on to allege there was clearly and internal engine problem with his new balanced and blueprinted engine.

Technical support representative had asked many times if the owner was sure there are no parts of the engine that is in contact with the airframe?

The conversation went like this (as they usually did), "All is well and we know what we are doing. There is definitely a problem with this engine. I can feel it [vibration] in the seat, in the control column and the instrument panel jumps around," the owner said.

From experience, I knew these symptoms weren't problems with the engine but, those related to an improperly installed engine.

Anyway, we dispatched a technical representative to the aircraft's location. And, as expected, during his preliminary inspection

> "Here was an owner and his "experienced" mechanic who were ready to disassemble an engine, and get attorneys involved all due to a simple clamp that was improperly installed."

our rep found a clamp was actually in hard contact with the engine cowling. The clamp was moved and the owner and rep went for a test flight.

After the flight, the owner reported it was the smoothest engine he had ever flown. Again: Eureka! Here was an owner and his "experienced" mechanic who were ready to disassemble an engine, and get attorneys involved all due to a simple clamp that was improperly installed.

A good rule of thumb is when you have issue like this it is very important to engage the right experts who have the experience to logically work the problem out.

## Airplane engines are not "hot rod" engines

Speaking of pseudo-engine experts, there are many of those types in our industry, particularly in the experimental aviation group, that look to highly modify their engines in order to gain more and more performance.

"If you are required to highly modify your engine for a specific mission, chances are you have the wrong aircraft, engine or combination thereof."

While tweaking out your IO-360 may sound like fun, extreme caution should be used when modifying any aircraft engine from its original type design. Airplane engines are not designed like car engines.

Remember the section on engine management when we discussed detonation margins? Modifying engines with higher compression ratios or supercharge boosting can be very dangerous and reduce those critical factory detonation margins.

If you are required to highly modify your engine for a specific mission, chances are you have the wrong aircraft, engine or combination thereof. The best practice is to leave the durability, detonation and safety testing to the engine manufacturer. Don't be the test pilot that gambles with your and your passengers' safety.

Testing like this can be very expensive in more ways than one – if you know what I mean…

# Continental fuel injection system calibration and maintenance.

If you own or fly an aircraft equipped with a Continental fuel injected engine, you will want to read this section very carefully. Proper fuel injection system calibration and maintenance is one of the most important items of your engine's ongoing health and performance. Unfortunately, it is also the most often overlooked.

When speaking at seminars and owner gatherings around the country. I always take a quick poll on fuel system maintenance. I simply ask, "Who here today has a Continental fuel injected engine in their aircraft?" Hands go up all over the room.

My next question is, "If you raised your hand and you can say without a shadow of doubt that your maintenance provider calibrated your fuel system when the engine was installed and checks it annually, raise your hand."

Without fail, even with 100 people in the room, only one or two hands will go up.

Then I have the audience look around the room at the show of hands. I say, "See what I mean?" Unfortunately, this is an example of how lacking we are as owners when it comes to being good stewards to our aircraft.

Overlooking such a critical piece of our engine's maintenance is quite likely the reason for so many of the ongoing cylinder, valve and performance problems that we see.

## You’ve got to go with the flow

The Continental fuel injection system is what we refer to as “continuous flow.” What that means is that the entire time the engine is running, fuel is flowing through the fuel injection nozzle and being delivered inside the cylinder regardless of the position of the piston.

The system is very simple and robust in design, and very seldom requires replacement or maintenance other than the need for an annual on-aircraft calibration.

Unfortunately, many mechanics don’t know about that requirement. Many times fuel system components are changed in an attempt to troubleshoot a problem. Had they known about the proper way to maintain and calibrate the fuel injection system, it would have saved them a lot of time and the aircraft’s owners a lot of money.

“Had they known about the proper way to maintain and calibrate the fuel injection system, it would have saved them a lot of time and the aircraft’s owners a lot of money.”

I’ve seen it first hand. Earlier in my career, I worked in the analytical department at an engine OEM. When fuel system components where returned under warranty and I performed the examination there were very few that actually exhibited any mechanical issues.

In fact, in many of these systems the problems were actually the result of contamination caused, quite possibly, by improper fuel system installation or calibration. All too often we found evidence that some type of contamination entered the system during engine or component change.

As part of our inspection process we methodically disassembled every fuel component before flow-testing. And it was during disassembly that we would find contamination. Once the contamination was removed and the component flow-tested, it performed flawlessly.

In a few cases, deterioration of the fuel system lines themselves was found to be the cause of the problem.

To help insure against these types of “preventable” problems leading to unnecessary component changes, Continental’s Service Instructions require that when installing a new or overhauled engine in the field the mechanic must flow one (1) gallon of fuel from the fuel tank-to-engine supply line prior to the final connection.

While it’s a good practice when servicing any engine, it’s especially critical when you are dealing with Continental fuel injected engines.

## The what’s, why’s and when’s of fuel system calibration

Before we go into the procedures on how to perform a fuel system calibration, I think it is very important we understand why it has to be performed.

The Continental fuel injection system is not complicated and its maintenance and adjustments are very simple if you understand how it all works. The purpose of this section is in no way intended for you, as owners, to start making adjustments to your aircraft’s fuel system.

These critical adjustments should be preformed by qualified mechanics that have the proper training, technical data and equipment to do it correctly. Adjusting the fuel system without the proper equipment and training could lead to engine damage or failure.

There are specific recommendations for when the fuel injection system needs to be checked, including:

- Fuel injection component change.
- 100 hour or annual inspection.
- System troubleshooting.
- Any fuel flow anomaly reported by the pilot

When the manufacturer or overhaul facility assembles a fuel injection system, those items are flow tested to ensure they will function to engineering design standards. They are typically flow tested using a Stoddard type solvent and not aviation gasoline. (Their respective safety men or women do not like things that have the potential to go boom.)

Once the system or component is tested, it is ready to install on the engine. There are many variables on the engine that cannot be replicated in the fuel system laboratory. These include specific head pressure, induction system differences, exhaust system differences and variability in specific gravity of solvent verses fuel.

Due to these variables, the fuel system must be calibrated for the installation. Continental Motors' latest revision of Service Information Letter (SIL) 97-3 provides detailed instructions for the mechanic to set the fuel system pressures properly. If your mechanic doesn't have a copy, they need to get one before attempting any adjustments to your fuel injection system.

Anytime you replace or overhaul an engine the fuel system must be recalibrated. In addition, the system must also be recalibrated following any component change in the fuel system.

If you replace the OEM fuel injectors with General Aviation

Modifications Incorporated (GAMI)-style injectors, the fuel system should be recalibrated. Even if you only clean the fuel injectors, the fuel system should be recalibrated.

There are numerous occasions in which fuel system components are changed in an attempt to troubleshoot an engine problem. All too often, this is done by mechanics who lack the proper training and understanding of the fuel system.

"Remember in an earlier chapter that I said, "the untrained, cheaper mechanic would cost you dearly."

Remember in an earlier chapter that I said, "the untrained, cheaper mechanic would cost you dearly." I have seen many instances where a fuel pump was replaced due to the engine quitting on rollout after landing, when all that the system needed was a simple adjustment to the fuel injection system.

## The calibration conundrum

Not surprisingly, I have had many people argue with me on whether fuel system calibration really needs to be done. These people believe that if the gauge in the panel reads the correct fuel flow on takeoff, the system is good to go!

While this thinking may seem correct, in reality it could not be farther from the truth. (The ironic thing about these pilots is that there's a good chance their engines routinely exhibit stumbling problems, chronic cylinder issues and reduced performance. However, their pride will not allow them to listen to the facts.)

I actually had a doctor argue with me about whether or not he should have the fuel system calibrated. He kept stating that if the fuel system reads correctly on the flow gauge, it should be OK. I suggested that he let me assist with diagnosis of some of his patients, after all, I did complete two semesters of anatomy and physiology in college.

"I suggested that he let me assist with diagnosis of some of his patients, after all, I did complete two semesters of anatomy and physiology in college."

Anyway, I made believer out of him after he allowed me to check his aircraft fuel injection system. After adjusting it in accordance with Continental's recommendations, the engine came back to life.

It ran smoother, cooler and produced more power than ever before. We agreed he would stick to medicine and I will stick to aircraft piston engines. In the interest of safety, please do not be one of these kinds of owners. Follow manufacturer's recommendations!

## This is how it's supposed to be done

Your mechanic does not require an elaborate piece of equipment like that depicted below to do a fuel system calibration. The Port A Test unit shown can cost anywhere from $4,000 to $5,000. Many quality shops have these types of units, but they are not required.

To perform a calibration, the mechanic simply needs two calibrated gauges as shown in the picture. Tools like this are available from most industrial or instrumentation suppliers. With the

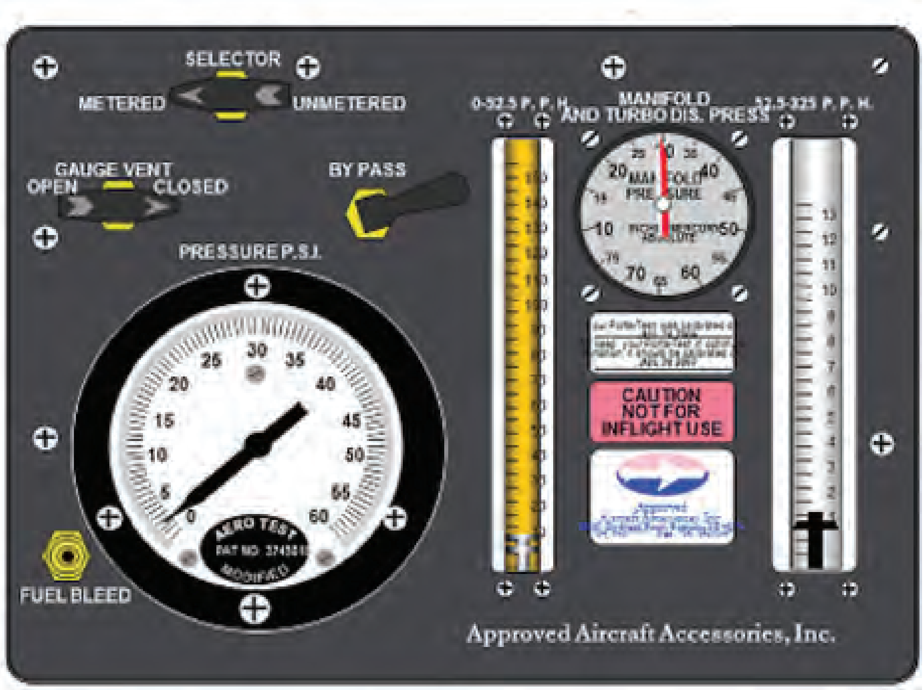


*Illustration of a Port A Test unit*

addition of a few fittings and hoses your mechanic is prepared to calibrate your fuel system correctly.

One gauge range is 0 to 60 in one (1) PSI increments and used to measure unmetered pump pressure.

The second gauge range is 0 to 30 in 0.2 PSI increments and is used to measure metered pressure.

If you have a turbocharged engine, the second gauge should be a differential type so the mechanic can reference compressor discharge outlet pressure as well. This pressure is often referred to as "upper deck." In the turbocharged engine, the reference is not to outside pressure but rather the boosted pressure before the throttle plate (upper deck pressure).

Each of the gauges mentioned should be calibrated by a qualified laboratory prior to use and should be checked periodically in order to ensure their accuracy when setting the fuel system performance.

With regards to troubleshooting, I often have owners call in and report their engine "dies on rollout." I ask about fuel system set up and they reply, "Oh, that's not it." Or, "We did that." In reality they don't have a clue about what I am talking about. They will tell me all about how their fuel-flow is "in the green" or at the "specified amount."

I get the same feedback from uniformed mechanics that have no idea how to calibrate the fuel system or the importance of said calibration to the operational longevity of the engine.

Funny thing is, if they read the Service Information Letter, they would know that fuel flow is not a target, it is pressure. Anyway, there are four things we need to check and set during calibration:

**WARNING!** *No adjustments to the fuel system should be made with the engine running!*

1. **Unmetered Fuel Pump Pressure**
   This adjustment is made at the specified idle RPM and is the output of the fuel pump only (unmetered pressure). Therefore, the unmetered gauge is connected directly to the fuel pump for reading. The setscrew located on the back of the fuel pump is used to adjust the flow.

2. **Metered Fuel Pressure or Nozzle Pressure**
   This adjustment is made after a series of full power runs. The target number is the full power metered pressure specification. The gauge is connected at the manifold valve, which is downstream from the throttle and control or metering unit. It is ad-

justed by turning the 5/32 Allen screw on the side of the pump, which is the adjustable orifice.

3 **Idle Speed**
This adjustment is made at the idle stop and controls the amount the throttle valve will open when it is set at the idle RPM specified by the manufacturer.

4 **Idle Mixture Rise**
This adjustment is made at the fuel control or metering unit depending on model of engine. We adjust this in order to obtain a 25 to 50 RPM mixture rise at idle. This means that when idle cut off is selected, the engine should automatically increase from 25 to 50 RPM. This allows for a slightly rich condition at idle and prevents stumbling of the engine during abrupt throttle movements at low power.

The entire fuel system must be set as a whole and not just the top end flow. I cannot stress the importance of having this completed by a competent mechanic that has the proper training, tools and calibrated instrumentation to complete the task.

## Truth is, panel gauges can lie

The reason we do not want to use the aircraft's fuel flow gauge for setting the fuel system is because part of the check is to verify accuracy of the aircraft instrumentation. There are many of you out there that are saying to yourself, "I have the most expensive engine monitoring system that money can buy and it was just calibrated by NASA engineering."

Please do not fall into that trap. I have seen many of the most sophisticated of engine monitors read inaccurately more times than I care to count. Obviously, this can be a real problem when it comes to fuel system calibration. If you are not cross checking accuracy, you are wasting time and money.

> "I have seen many of the most sophisticated of engine monitors read inaccurately more times than I care to count."

During fuel system calibration your mechanic should use a calibrated strobe tachometer to verify actual engine RPM. In fact, we were recently performing a fuel system calibration on a Beechcraft Bonanza and we found that the aircraft's tachometer was reading in error by nearly 150 RPM. It doesn't take a Master Mechanic to know that this error can be a real problem when calibrating the fuel system.

The good news is that fuel system calibration is relatively inexpensive. The average time required to complete fuel system calibration is around four hours. Now, that is for an aircraft that does not already have the cowling off for some scheduled maintenance.

When it's done in conjunction with an annual inspection, calibration should add no more than three hours to your bill. Believe me folks, it is cheap insurance against cylinder issues, lack of performance and, best of all, it helps improve safety. Do not ever let some wizard on the Internet or website chat forum tell you it is not required.

## Seeing is believing

Years ago, I was part of an annual Beechcraft owner's meeting and the participation varied from 100 to 200 owners and their aircraft. We would put on seminars and discuss ways to maintain and operate their engines effectively. One subject was always fuel system calibration.

One year, I decided we would pick six aircraft at random and check the fuel system calibration. My thought was this test was either going to prove my point that mechanics don't properly calibrate the fuel systems or it was going to prove that I was wrong and I would forever quit bitching about the importance of fuel system calibration. Either way it was a win for the attendees.

Not surprisingly, all aircraft selected were outside specified parameters and many were problematic with rough idle, quitting on rollout, lack of engine performance and so on.

> "My point was driven home and now at least those attendees believe when they hear me preach about the importance of fuel system calibration."

Needless to say, I was somewhat relieved that I did not make an ass of myself. But at the same time, troubled by the fact that so many owners were not giving their engines the proper maintenance.

Many of the owners whose aircraft were select commented on how well the engine ran after our technicians properly adjusted the system. Pilots reported everything from no more stumbling, to engines running cooler, aircraft climbing better, smoother engine operations – all the way to their engines even having "more power."

Eureka! My point was driven home and now at least those attendees believe when they hear me preach about the importance of fuel system calibration. One small step for this man…

In summary, if you fly an aircraft equipped with a Continental Fuel Injected engine, make sure your maintenance provider is familiar with fuel system calibration. It's as simple as asking three questions:

1. Did you set the fuel system in accordance with Continental instructions?

2. Were my unmetered pressure and metered pressure within specifications at annual?

3. Do you have the correct gauges for setting up the fuel system?

If you get funny looks or non-confirmatory responses to any of these questions, chances are your current mechanic will end up costing you a lot of money in the long run.

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> "In summary, if you fly an aircraft equipped with a Continental Fuel Injected engine, make sure your maintenance provider is familiar with fuel system calibration."

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# Cylinder baffling and keeping your engine cool.

Another topic of interest for any aircraft owner should be the proper maintenance of your engine's baffling. I've witnessed too many instances where an aircraft owner or their mechanic have installed a $30,000 to $90,000 engine only to use the old deteriorated baffling. Why not spend a little bit more and do all you can to protect that big investment?

In reality, I don't think it is so much a question of economics but rather lack of understanding about the functions and performance of an engine's baffling.

With fuel system calibration being number one, neglecting baffling condition is probably the number two most common maintenance issue I see under the cowling. The fact is, engine baffling that is left in a state of disrepair will likely result in reduced cylinder life and other operational performance issues.

## Demystifying baffling

Engine baffling serves a crucial role in cooling the cylinders evenly and keeping the entire engine within specified temperature parameters. Small imperfections or problems in the baffling can result in dramatic effects to the cylinder and oil temperature.

Some of the detrimental effects can include accelerated

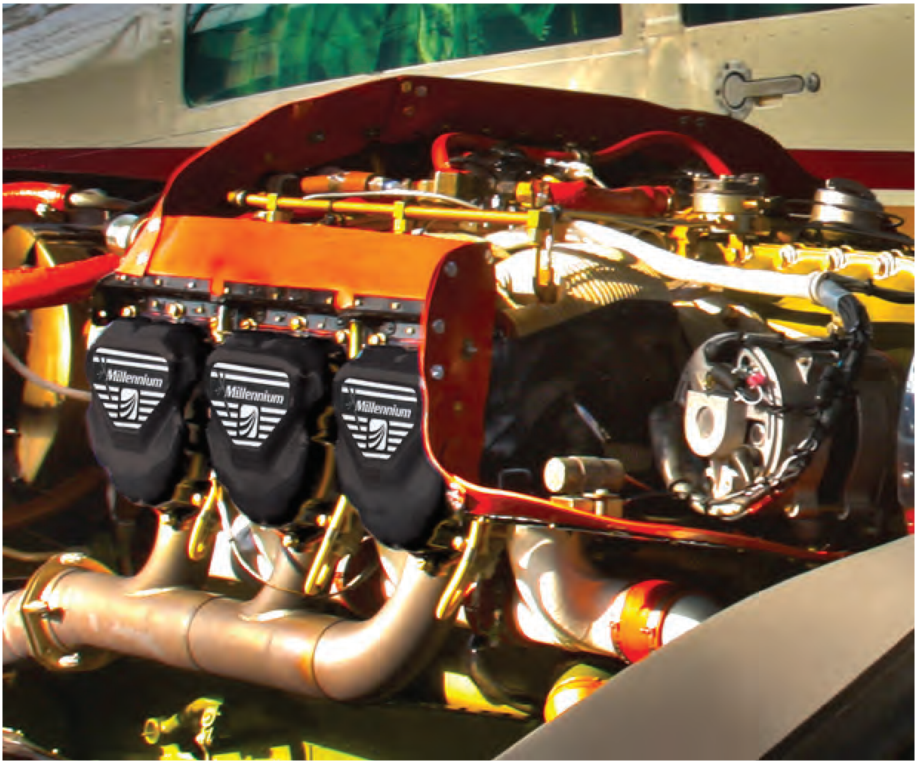



*Photo courtesy of RAM Aircraft*

wear of cylinder and valve train components, glazing of cylinders and in some cases reducing detonation margins to dangerous levels.

Over my many years as an A&P and technical representative, I have assisted in solving cylinder head temperature issues many times. In the majority of cases abnormal cylinder head temperature is usually not the cause of some manufacturing or material defect in the cylinder itself.

In fact, as I've covered elsewhere in this book, there are many things that can influence cylinder head temperature, including fuel system calibration, engine timing, flight profile, climate and most of all damaged or improperly installed baffling.

I have witnessed many mechanics chase cylinder head temperature issues by adding fuel on the injection adjustment well above the manufacturer's recommendations. This is merely placing a Band-Aid™ on the root of the problem!

Owners and mechanics can be quick to blame the cylinder's manufacturer, but in my 30-plus years have I found only a couple of instances where that was indeed the cause of the problem.

When troubleshooting engine temperature problems, I always ask the owner or mechanic about the condition of their baffling. Without question, 100% of the time it is reported as "okay," "good" or even "perfect."

The fact is, as I probe further into the problem, more times than not, the condition of the baffling was, in fact, nowhere close to being "okay."

### Bird 1... Baffling 0

I remember one instance where the owner reported high cylinder head temperature problems. We assisted in troubleshooting over the phone for several days and were told the baffling was perfect. Finally I traveled to his location and when I examined the airplane I actually found the remnants of a bird's nest in the baffling. The bird had long ago moved out.

> "He and the owner were ready to remove cylinders, change the fuel pump, etc. Anything but address the actual problem."

I guess birds don't like cylinder head temperatures above 400 degrees either! I just had to ask the mechanic if this is was his idea of good or perfect baffling? He and the owner were ready to remove cylinders, change the fuel pump, etc. Anything but address the actual problem.

Anyway, we cleaned and resealed the baffling and that immediately brought the cylinder head temperatures down to normal levels.

The owner was very embarrassed and offered to pay all my expenses for the trip. I declined and advised him we would use this time to work with his mechanic. Today, (not because of me) the mechanic is one of the best in the industry. I encouraged him to attend many of the recurrent training classes on engines and airframes. While experience is good, training is sometimes better for all!

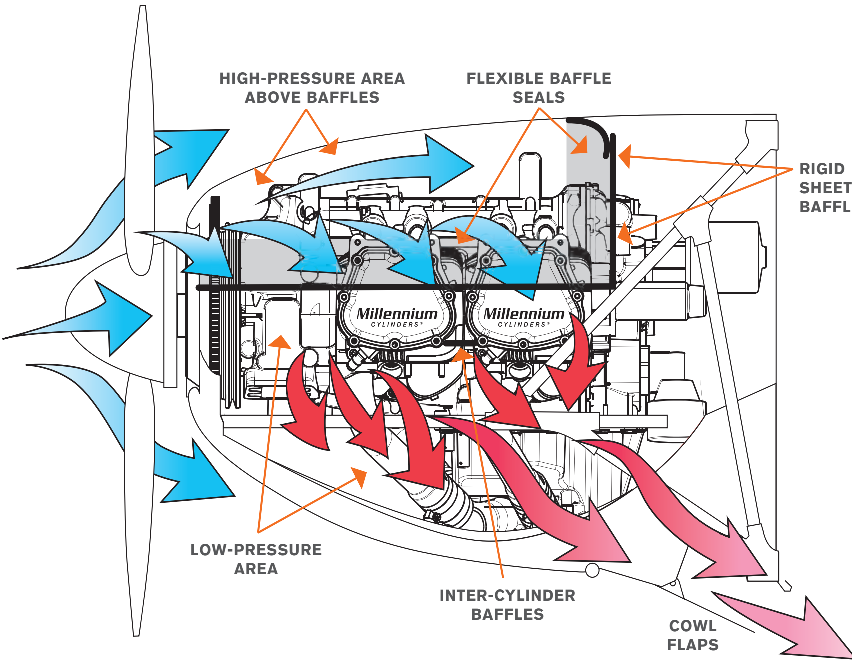
## Don't be bumfuzzled by baffling

In order to appreciate the importance of engine baffling, I think we must understand its function and how it works. The illustration on page 101 shows how the airflow moves through most general aviation aircraft cowlings. In the majority of installations the cooling air flows down through the cylinders and out through the bottom of the cowling.

This airflow is accomplished by creating a confined high-pressure area through the proper placement and installation of the baffling. The higher pressure on top of the engine allows for the air to flow directly to the low-pressure area on the bottom.

The baffling constrains the air so it flows directly around the cylinders. The inter-cylinder baffling directs cooling air to the vital portions of the cylinder head and in some cases helps to balance the cooling airflow to eliminate hot spots.

When properly installed, the baffling is designed to create




> "When properly installed, the baffling is designed to create a seal between the upper and lower portions of the engine."

a seal between the upper and lower portions of the engine. It is very important that the rubber pieces of the baffling conform to the engine cowling, allowing no air to escape over or around.

This is why it is vital that all air gaps be sealed properly. The general rule of thumb for most installations is to direct as much cooling air as possible down through the cylinders. The residual heat is carried away through the bottom of the cowling. For those of you who fly aircraft equipped with cowl flaps, you are able to regulate the amount of air flowing through the cylinders simply by regulating pressure within the cowling.

Check your engine baffling carefully during preflight inspections and make sure your maintenance provider checks it closely during the next 100 hour or annual inspection. You do not have to remove the cowl and do a detailed inspection during preflight. Just a quick glance in the cowling will let you know if the baffling is problematic or perhaps folded the wrong way. You can review with your mechanic how the baffling should look during your preflight inspections. Here are just a few items to look for:

- Cracks
- Incorrect fit
- Incorrect positioning
- Gaps not sealed properly
- Torn or cut rubber seals

During engine installation, make sure your engine baffling is either in pristine condition or is replaced. This small investment in new or repaired baffling will protect the larger investment you made under the cowling!

For example, I recently overhauled the engine in my father's Alon Aircoupe and that overhaul included new baffling. Now, thanks to the new powder-coated baffles and rubber seals, the trusty Continental C90 gets lots of cooling air love.


*The Ross family's 1966 Alon Aircoupe was recently overhauled and now has updated baffling.*

"My dad is very proud of his airplane and enjoys telling folks how graduates of the University of Alabama Aerospace Department never do anything half ass."

Not only does the new baffling protect the engine but now my dad is quick to raise the top cowling of the little Aircoupe to show off his beautiful new engine compartment. Just like a Corvette owner would do if he had a whole lot of chrome under the hood.

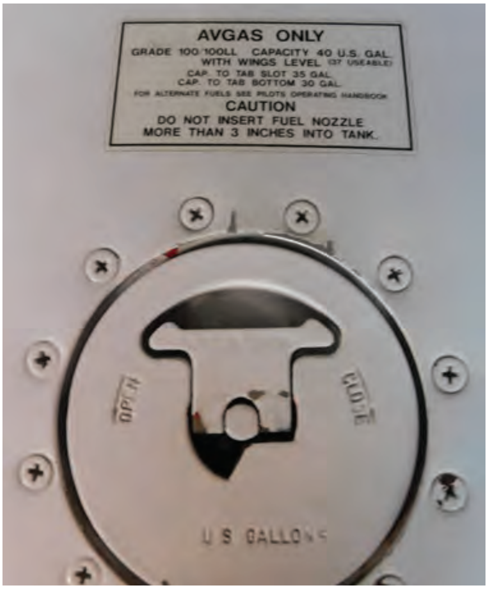
My dad is very proud of his airplane and enjoys telling folks how graduates of the University of Alabama Aerospace Engineering Department never do anything half ass.

The attention by you and your mechanic to ensure your aircraft's engine baffling is installed and maintained in accordance with manufacturer's instructions will go a long way in providing cylinder and overall engine longevity.

# It's a gas: 100 LL and alternative fuels.

One of the biggest concerns regarding the future of private aviation is the ongoing availability of leaded aviation gasoline. Depending on which aviation event you attend, every few years or so this distress swells up to epidemic proportions. And after a while, the concern subsides and we all get to worry about other things.

An example that sticks out in my mind happened a couple of years ago when an aircraft owner cornered a couple of us at an airshow. This particular fellow was very hot under the collar regarding our company's seeming lack of work towards developing an "alternative fuel" powered engine.




We assured him that our company, along with every other piston engine OEM and PMA manufacturer at the time, was engaged and working on the problem. We cited specific examples and tasks we, and others, had accomplished to date.

After a while, he finally calmed down and then the other guy with me said, "You know, one day the sun will burn out, who is working that problem?" The owner sort of smiled and shook his head. As he left said, "Now I'll go worry about the sun."

The point here is that all of the aircraft engine manufacturers are continually looking for efficient ways to work with alternative fuels. Also, it is extremely unlikely that Avgas supplies will be cut off quickly without sufficient or suitable alternatives available.

## Bill goes to Avgas class

Several years ago I was asked to speak about the future of alternative fuels to the Cirrus Owners and Pilots Association (COPA) Migration in Dayton, Ohio. At first I thought they have the wrong person and tried to convince them to find a more suitable spokesman on the topic.

After all, there were engineers and consultants working the problem that could speak much more intelligently than I could on the subject. However, they would not change their minds and that forced me to do some extensive research, which I did. I can tell you that it really opened my eyes about what aviation fuel is all about.

This was a very good reminder that the best antidote for worry is education. Yes, the future of Avgas problem is real, but it's not the end of the world.

## "O" is for octane

Many pilots and mechanics believe the only concern with regard to what fuel they can safely use in their airplane is its octane rating. Therefore, if the local gas station offers a high octane like


100, we are good to go for our aircraft engine.

Unfortunately this could not be farther from the truth. In fact, the solution is much more complicated than just the octane number.

When we think about the fuel's octane rating, think about it as the fuel's ability to hold its fire longer. The fuel with higher octane has the ability to delay combustion and allow the spark to ignite the entire fuel/air mixture and burn smoothly.

For example, when used in an aircraft engine, fuels with lower octane ratings – like 93 octane auto fuel for example – can spontaneously combust, leading to detonation, internal engine damage and quite possibly catastrophic engine failure. The combustion process in an aircraft engine is not a bang and push on the piston. It is rather a controlled burn and push on the piston.

"For example, pump-grade automotive gasoline – Mogas for short – does not have the properties that will allow it to burn smoothly in aircraft engines."

In fact, when we think of "bangs" in aircraft engines, we are actually thinking about detonation. Detonation is not a controlled smooth burn of the fuel air mixture. For example, pump-grade automotive gasoline – Mogas for short – does not have the properties that will allow it to burn smoothly in aircraft engines.

That's why when you are trying to make a comparison between aviation gasoline (Avgas) and Mogas octane rating is just one of the fuel's many components you need to consider.

## Ethanol and airplanes don't mix

The first issue with Mogas is ethanol content. While it's fine for most cars, ethanol can have very devastating effects to the aircraft fuel system, fuel tanks, O-rings and fuel injection components. These components can be deteriorated by ethanol, and that can cause safety of flight issues through contamination and loss of function.

That's not all that's wrong with ethanol: it also has undesirable vaporization properties, which among other things, can lead to vapor lock issues in fuel-injected engines. In addition, on very hot days, Ethanol can vaporize right there in the wing tanks, which reduces the real amount of fuel you have on board.

Lastly, ethanol loves water. When it's in your engine's fuel system it can actually extract moisture from induction air to the point where the air/fuel mixture is water-saturated and you lose engine power.

If you're ever temped to buy fuel for your airplane at a regular gas station please keep in mind that Mogas manufacturers have very little control of their fuel's total ethanol content even though the dispenser and station may proclaim to sell only 100% gasoline.

The tanker before the load of "100% gas" could have been filled with fuel containing a high level of ethanol. I understand we are only discussing residual ethanol left in the delivery tanker but when it comes ethanol's negative effects on airplane engines, a little goes a long way.

In fact, those fuels that proclaim to have only "10% ethanol" can actually have much higher amounts. Currently, there is no control or check to accurately verify the amount of ethanol contained within a given amount of fuel. Conversely, Avgas producers are bound by very tight regulation and control to ensure there are not even trace amounts of ethanol present.

## Not all fuels are created equal

Another thing to keep in mind is that even though your aircraft's engine has an STC approval to run on Mogas, these fuels can vary greatly with regard to formulation specifications.

For example, if we purchased Mogas at a station in Alabama and then again at a station in say, Texas, chances are that the fuel's actual specifications, such as anti-knock constituents, additives and octane will be quite a bit different.

Comparatively speaking, if we purchase Avgas anywhere in the United States the specification is required to remain in the

center of the proverbial formulation goal post. That means there is very little, if any, room to deviate from the fuel's published specifications. Few people know this, but another problem with using Mogas in aircraft is the fuel's durability over time. Avgas has a very long shelf life as compared to standard pump gas. I don't think I have ever seen Avgas go bad, but I sure have seen Mogas go bad quickly after a very short time in my weed eater.

Even the transportation of Avgas is strictly controlled. If a tanker is used to transport Avgas, that is all it can legally transport. It won't be delivering 100LL to the airport today and 93 octane Mogas to the local Quickie Mart tomorrow.

## Avgas and Jet-A don't mix

To give you an idea of how serious this can be, let me tell you about an incident that happened at an airport near my hometown. It all started innocently enough when a fuel tanker truck delivered a load of 100LL Avgas to a local airport. The problem was just prior to that the tanker had delivered a load of Jet A to another FBO. As you can imagine mixing fuel types goes against the approved practices for delivering any aviation fuel.

While the container was virtually empty when it took on its load of 100LL, there was enough residual jet fuel by volume to cause engine damage to several aircraft fueled at this airport. The biggest problem was a rash of pre-ignition/detonation events caused by the Jet-A contamination. It could have been so much worse.

Thankfully no one was hurt and the fuel supplier took full responsibility replacing all the damaged engines. It is my understanding that based on this event the petroleum company implemented even tighter restrictions to ensure this could never happen again.

## Life after 100LL

As the refiners continue to work the alternative fuel issue, the various piston engine and component manufacturers are working behind the scenes to ensure that even if the tetraethyl lead (TEL) faucet was turned off tomorrow by the EPA, we could continue to fly with some slight modifications to our aircraft.

Those modifications may include lowering the cylinder's compression ratios or employing intelligent ignition systems that can sense knock.

But, owners flying higher compression, normally-aspirated


"But, owners flying higher compression, normally-aspirated engines – 8.5:1 or higher – may well not have it quite so easy."

engines – 8.5:1 or higher – may well not have it quite so easy. Why? The biggest problem again is detonation. I've covered detonation back in Chapter 2, so we won't get into it again here.

If your aircraft has a turbocharged engine, which has lower compression ratios already, your transition to these alternative fuels may be eased. Also, many early radials and opposed-piston engines will probably operate well on some of these proposed new fuels.

In the case of my Stearman, which is equipped with a Continental W670 radial engine with a compression ratio of only 5.4:1, I'm confident that it will safely run just about any alternative fuel with 73 octane or above and will keep me flying.

It is a shame that good quality Alabama moonshine can't be used as an alternative fuel for my airplane. However, I think we should drink the whiskey and leave the development of the alternative fuels to the petroleum companies. I am confident there will be a suitable alternative without compromise very soon.

# Magneto Maintenance 101.

Although the basic magneto has provided very reliable service to aircraft operators for over 100 years, it's still a very misunderstood part of your engine. For example, while many owner/pilots think it needs the aircraft's battery to operate, the fact is your magneto is a self-contained unit cable of full functionality that is independent of the aircraft's electrical system.

There is no battery power required to start or sustain an aircraft magneto operation. Oh, there are a few that would say, "Without the battery (to turn the starter) the magneto is not able to function."

Obviously, they did not grow up on our airport is South Alabama where hand propping was the normal procedure. Many of the

"Therefore the only way to start the engine was the "Armstrong Method.""

aircraft that I cut my proverbial pilot's teeth on had, and still have, no electrical system. Therefore the only way to start the engine was the "Armstrong Method."

The basic aircraft magneto uses a strong rotating magnet inside a coil. There is a voltage produced in this primary coil, which is then stepped up even higher in a secondary coil. This is achieved by having more windings in the secondary coil than in the primary. The increase in voltage is enough to excite the spark plugs to then spark-

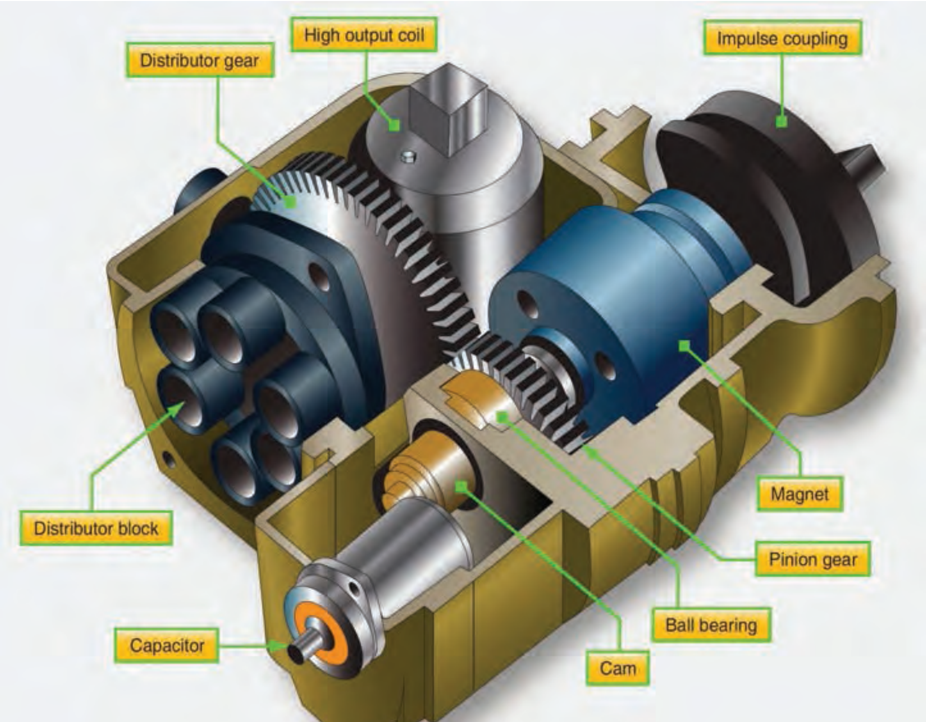


*Illustration complements of Quality Aircraft Accessories*

ignite the fuel/air mixture for combustion.

While the magneto is very reliable and robust, it is intolerant of neglect or abuse. This section is not intended to make you an expert on magneto theory, function and maintenance but should prove helpful in understanding the periodic maintenance recommendations by the respective manufacturers. As pilots and owners, if we understand these recommendations and why they are important to safety, we can ensure our maintenance provider is correctly following them.

## Understanding the mag-check

The magneto check is one of the first things we learn as


student pilots. Run the engine up to a specific RPM and switch to the right mag then the left. If you see a "suitable" drop in the engine's RPM you're good to go. Or are you?

One of my first jobs as a pilot (besides flight instruction) was flying charter in various piston-powered aircraft. Often times we were paired with another pilot because we had a contract with the Army Corps of Engineers and the rules required two pilots, even if we were in a Beech Baron with a single yoke.

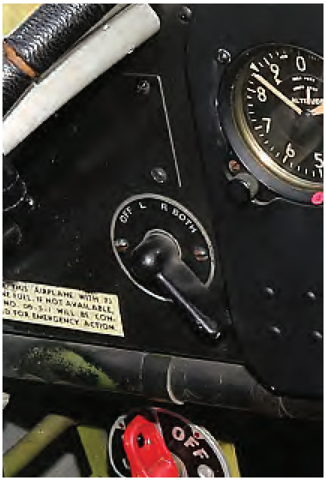
We had another pilot on our staff named Charlie. Charlie and I flew a lot together, and he taught me a lot about flying and engine operations. He was the in the first class of Flying Sergeants to graduate from Columbus, Mississippi during the onset of World War II.

During his career he flew B-25 bombers and then had a 34 year career as a Captain with Pan Am. During the late 80s, he drove a pristine 1967 Ford Mustang. Before the Dos Equis beer commercial actor, he was truly the "world's most interesting man!" Well, he was to me anyway.

> "Before the Dos Equis beer commercial actor, he was truly the "world's most interesting man!" Well, he was to me anyway."

Early on in our flying partnership, he told me the funniest story about magneto checks. When he was in primary training and just about ready to solo the Stearman, he would watch the instructor reach up and move the ignition switch back and forth and notice a little RPM drop on the engine.

For each and every flight he would watch in confusion as to why the instructor went through this ritual. Was it superstition, ode to the flying spirits or nervousness on the part of the instructor? Whatever the reason our friend Charlie had no idea why the Army Air Corps instructor repeated this odd ritual.



Original Stearman Dixie magneto swtich

So when it came time for him to solo, Charlie reached up and did the same pre-takeoff ignition ritual as the instructor.

It wasn't until after he soloed that his instructors covered magneto checks in ground school. Remember, this was a civilian/government contractor, after all and well, some-times they do things a bit odd.

The point here is, even today, with all the information available about run-up mag-checks, do we still get caught up in the ritual and not really look at the ignition system as a whole? No doubt we all do.

**Does the mag-drop really mean anything?**

After many years and thousands of hours in the left-seat, I've learned that simply having an "acceptable magneto drop" dur-ing engine run-up is not necessarily a good indicator of the overall health of your magneto system. Even if the drop is only 50 RPM, there are many issues that could well be lurking inside the magneto that are just waiting to come out and cause problems.

During my career as an A&P I have personally performed

> ““Acceptable magneto drop” during engine run-up is not necessarily a good indicator of the overall health of your magneto system.”

analytical inspections on many engines that were destroyed due to lack of, or improper, magneto maintenance.

Yes, I know there are many “experts” in the general aviation industry professing that you can learn everything about the health of your magneto by simply performing a lean of peak test while in flight.

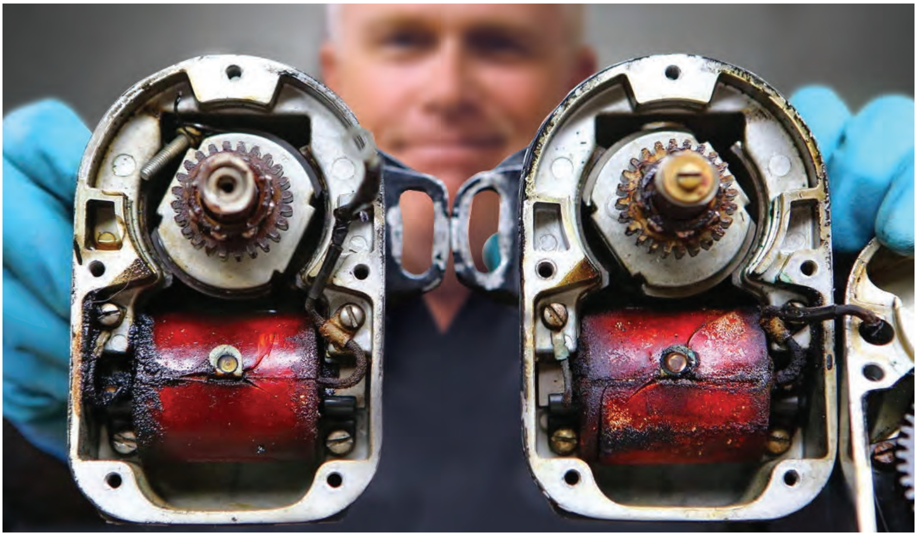
I also hear a lot of talk about how today’s sophisticated engine monitors are capable of detecting imminent ignition system issues. While to some degree this can be true – such as determining spark plug performance, spark plug lead and minor magneto issues – even the best engine monitor is not capable of predicting the future.

Contrary to the opinions of many, a lean of peak magneto test or engine monitor cannot predict some of the serious issues I have witnessed with ignition systems. These include worn or fractured gear teeth, lubrication distress, cracked housings – the list goes on and on. While a magneto problem may not seem too serious; believe me it can be disastrous.

## Magnetos need maintenance too

There are very specific maintenance checks recommended by the manufacturer that are extremely important to both the safety and reliability of the engine and aircraft.

The problem is most aircraft owners, and some mechanics,



are not aware that these recommendations even exist. For example, manufacturers of both the Bendix-style and Slick magnetos "recommend" a 500-hour inspection for their units.

Personally, I know very few owners that actually know of, and fewer who actually comply, with this recommendation.

"It's only a recommendation," they'll say. Well, that's true. But, these are often the owners who are plagued with difficult starts, a rough-running engine, and an ongoing list of other unscheduled maintenance practices. Remember, the purpose of scheduled maintenance is to prevent unscheduled maintenance. In addition, Bendix-style magnetos have a recommended four-year in service or five-year from date of manufacture replacement/overhaul, whichever occurs first.

Therefore, if a Bendix-style magneto has been on the shelf for three-years and is then installed on an engine, it only has two-year-useful life remaining before recommended overhaul. Again this is a recommendation, but following it can be beneficial to ensure system reliability and flight safety.

Why do these particular units have this type of recommendation? Magnetos that sit on the shelf can be severely damaged by corrosive attack due to inactivity. Conversely, magnetos that have been in service for a period of time can become worn due to contamination and operation. Magnetos that house excessive dirt and electrolytic debris are prime candidates to ruin your day.

Oh, they may check fine on the ground during run-up, but they may well have internal issues that will show up during your flight. Some scenarios could be cross-tracking of the spark within the distributor block. If the spark reaches the incorrect pole, a pre-ignition event can occur leading to detonation and engine failure. Cracks in the distributor drive gear can lead to fracture of the gear and stop the distribution of spark to different cylinders.

"Remember, the purpose of scheduled maintenance is to prevent unscheduled maintenance."

I performed several analytical inspections over the years on pre-ignition/detonation events that exhibited fractured away teeth on the distributor gear. Once the gear could no longer be driven, the distributor finger would fire only on one cylinder. This leads to a pre-ignition/detonation event and destroying the engine.

Even though I wish they could, engine monitors cannot predict events like these. Like with many parts of your aircraft and engine, the only way to help keep issues like these from ruining your day is to follow manufacturer's recommended maintenance, inspection and replacement intervals.

Think about it: we service the engine during an oil change and compression test even though it is running fine. Why should we not service and care for our magnetos as well?

## Keeping your magneto healthy.

Think about it: we change oil in the engine, but we don't change oil in magnetos? But we need to.

During the typical 500-hour engine inspection the maintenance provider should disassemble, clean and inspect the magneto internal parts. At the same time, the breaker points and condenser are normally replaced and the magneto is lubricated. In addition, inspection of the gears for cracks or abnormal wear is very important to the function of the magneto and health of the engine.

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> "Having an impulse coupling that is not functioning properly can lead to the engine firing in full advance timing and this lead to a kickback during starting."

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The impulse coupling, (if equipped) is inspected for excessive wear and correct functionality. The impulse couplings are a spring-loaded component that aids in engine starting by accelerating the rotating magnet and retarding the timing. Having an impulse coupling that is not functioning properly can lead to the engine firing in full advance timing and thus lead to a kickback during starting. Kickbacks can wreck your starter and severely damage engine components.

After inspection, the magneto is reassembled, tested and installed back on the engine. Next, the magneto-to-engine timing is set in accordance with the engine manufacturer's instructions and specifications.

If we want the most out of our engines and continued longevity, follow the manufacturer's recommendations for continued airworthiness.

# What is this PMA thing and how will it help me save money?

For many reasons, the dream of private aviation has become increasingly unattainable for many pilots. From the cost of Avgas, to flight training, to insurance, to engine overhauls, to, well everything else that goes into owning and flying a small airplane – costs are rising faster than Nick Saban's salary at the University of Alabama – *Roll Tide*!

Of course there are a lot of reasons for these increases: production, manufacturing and liability costs for aircraft, engine and avionics manufacturers are going up each and every year.

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"Costs are rising faster than Nick Saban's salary at the University of Alabama – *Roll Tide!*"

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As a result, the dream of flying for fun or as a career is nearing the point of financial impossibility to many of us. So, unless we can find less expensive alternatives and ways to mitigate costs of ownership, it is possible that general aviation, as we know and love it, may fade west into the sunset.

## PMAs are a money-saving solution

Since this book is about engine operations, I'm going to


stick to the area that I'm most connected to: engines and controlling the cost of their ongoing repair and overhaul. As I mentioned before, the combination of high liability and production costs, combined with the shrinking market for engine spare parts, has driven these costs through the hangar roof.

Or, it would if it were not for companies like Superior Air Parts and others, who have built their businesses supplying FAA-approved Parts Manufacturer Approval (PMA) parts for general aviation engines and aircraft.

Ever since Superior's inception in 1967 as a PMA manufacturer, our number one goal as a PMA provider is to help Make Flying More Affordable. At the same time Superior will never compromise quality in order to achieve that goal.

Components manufactured under an FAA-approved PMA are precise fit, finish, and functional alternatives to the OEM part.

"Components manufactured under an FAA-approved PMS are precise fit, finish, and functional alternatives to the OEM part."

Under the PMA approval process, each part must be eligible for specific application on FAA certificated products.

To get the FAA's approval, a PMA part must demonstrate through documentation and testing that it meets the performance of the original OEM component it is created to replace. Many PMA providers like Superior Air Parts actually alter the design used to manufacture the original part to create a more updated product.

One way Superior has done this is by using the newest materials, engineering and manufacturing techniques to produce its line of PMA products. We must be doing something right; today Superior Air Parts holds FAA PMA approvals on nearly 3,500 parts for piston aircraft engines.

Also, being much smaller companies than the major engine manufacturers, Superior and many other PMA providers have substantially lower overhead, which allows them to invest more resources into selecting the best new materials, fine-tuning the engineering and improving the manufacturing processes. We also work very closely with owners, operators and maintenance providers to reduce cost and increase the lifecycle of key parts.

## So how can PMAs help you?

The short answer is, by saving you money. In many cases, lots of money. One of the reasons that PMAs exist is in order to stimulate some competition within the aviation industry.

Without PMA providers like Superior Air Parts, the big engine OEMs would have a complete monopoly on the industry and it's a safe bet that the costs of aircraft ownership would be even higher than they already are.

Just look at what "PMAs" have done for the automotive aftermarket business. Think about it for a minute – when was the last time, other than warranty work, that you went to a new car dealer to buy parts? Probably never. Why? Because they just cost so much more than what you can get from an auto parts store or third-party mechanic who uses "aftermarket" parts.

For example, a new alternator for a 2009 Toyota Camry costs around $370 from a dealer. The aftermarket equivalent from an auto parts store is under $100. Now, apply that same math to aircraft parts and it's easy to see the value that PMA parts bring to you as an aircraft owner/operator.

In many cases, that competition is the only thing helping to control the cost of replacement engine and airframe parts. For example, according to the owner of a highly respected engine overhaul shop, the camshaft for a left-hand turning Lycoming LTIO-540 engine from the engine manufacturer costs over $5,000 – for a camshaft! The main reason is there is no PMA part available.

However, Superior does hold and FAA PMA to produce a replacement camshaft for a right-turning TIO-540 engine. The cost for that part is around $800 retail. That's around a $4,200 less than the "factory" part. How does the OEM justify this enormous price difference? Simple: There is no competition.

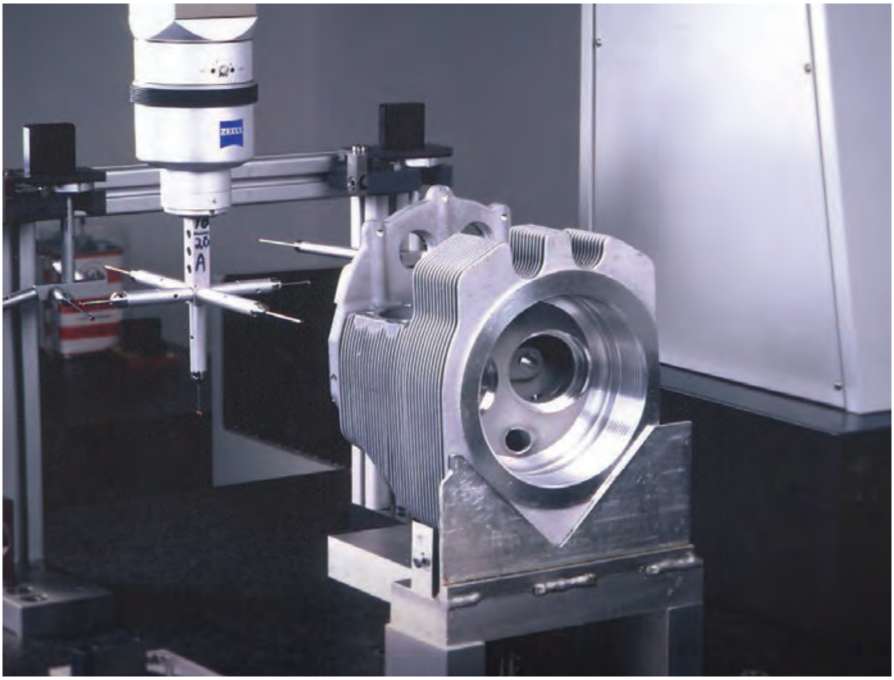
Of course, this is just one example of how PMA part pricing helps maintain a competitive balance. And that lack of any competition is why the engine's original manufacturer can justify (get away with) this huge price difference.

And believe me, in the eyes of the FAA all these parts are exactly the same, whether they are from Alabama, Pennsylvania or Dallas.

## It costs a lot to save anything at all

So why not simply PMA a camshaft for an LTIO-540? Well, between engineering, production and FAA approvals, it costs a lot of money to PMA a part today. Even if you sold two PMA'd camshafts to every operator, there just aren't enough LTIO-540s in the entire GA fleet to recoup the up-front development and approval costs.

While Superior would like to be able to PMA every part, the company, like all PMA producers, is continually challenged to identify which parts offer the return-on-investment potential to make the



investment worthwhile. As you can imagine, gaining PMA approvals from the FAA is a long and very expensive process.

And that process is becoming more prohibitive every day. In an increasing number of instances the PMA approval is actually requiring more data than the original manufacturer submitted during the Type Certification process.

The very intensive investment in time and manpower is the largest barrier to entry – the foundation of monopolies – that the major engine manufacturers rely on to enable them to keep the costs of their replacement parts at their current high levels.

However, with modern tools, efficient organization and the benefit of the experience gained through years of field service and related issues, Superior is able to meet both the FAA's and our customers' goals of high-quality products
at lower prices.

## Lucky for you PMAs are here to stay

Cost-minded aircraft owners and maintainers are realizing that PMA parts are one way that they can save real money while taking advantage of new, and often improved, manufacturing and design technologies, which enable PMAers to produce an even wider array of products.

It's not only owner/operator/maintainers that are taking advantage of what PMAs have to offer. Many commercial aircraft and engine manufacturers are themselves now supporting PMA efforts.

In many cases if it weren't for PMA parts, a whole lot of smaller, independent commercial operators would be out of business – and a whole lot of owners of classic aircraft would not be able to fly their airplanes.

"One of the reasons that PMAs exist is in order to stimulate some competition within the aviation industry."

They realize that the ability for PMA producers to continue to grow will help their aircraft stay in the air. It just isn't cost-effective for an aircraft manufacturer to keep producing parts for an aircraft that has been out of production for 15 or more years.

Thankfully for all of us, that role has been taken on by a growing number of PMA producers.

Heck, if it weren't for companies PMAing out-of-production parts, many aircraft types would have been grounded a long time ago.

## PMAs: Don't knock 'em until you've tried 'em

I hear aircraft owners and mechanics saying all the time that they don't want PMA parts in their aircraft for this, that or whatever reason. I'm here to tell you that it's all based on a lot of misinformation and misdirection. Like I've said many times: show me the proof that PMAs are not as good as the original parts?

So far no one has been able to offer credible substantiation to PMA parts being in any way inferior to the "original" parts. Why? Because there aren't any examples. All FAA-approved parts are equal in every respect.

Yet, even with the well-established track record for quality, innovation, value and performance that PMA parts have earned, the major engine manufacturers continue to waste valuable time and resources spreading anti-PMA propaganda.

But that tune is also changing. In fact, one well-known engine manufacturer recently purchased a competing PMA parts

manufacturer to get into this side of the business themselves. Why? They see how successful Superior has been and they want to be part of it.

That's reason enough to toss all that "apples-to-oranges," OEM vs PMA claptrap out the window. Again, from a safety or engineering standpoint, today's FAA approved PMA parts are on par with anything produced by the original engine manufacturers. Period.

Or, as stated by the FAA in FAA 8110-42: "Each and every replacement part that Superior Air Parts offers must meet the same stringent quality and performance guidelines, as well as the same design control, quality control and documentation as the original TC holder must provide for approval."

So the FAA-approved PMA parts that Superior Air Parts offers to a grateful general aviation market are the result of:

- Superior's Real Engineering
- Superior's Real Testing
- Superior's Real Quality Control
- Superior's Real FAA approvals and
- Superior's Real Commitment to providing our customers with the best products and after-sales support possible.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Making Flying More Affordable Since 1967

# What we've got here is "failure to communicate."

Throughout this book, I probably sounded like a broken record when it came to stressing the importance of following instructions from the people that designed and made the engines and parts we fly. As an aircraft owner myself, I can't help but wonder why is it that so many other owners choose not to follow manufacturers' recommendations?

My only guess is that we get caught in the trap of trying to save money and the shortest route to that is obviously not following the guidelines set forth by manufacturers.

Somehow we believe – and a number of "experts" on the Internet push this idea – that the manufacturer is creating busy work or repairs that really do not need to be done.

The fact is, this notion could not be farther from the truth.

"My only guess is that we get caught in the trap of trying to save money and the shortest route to that is obviously not following the guidelines set forth by manufacturers."

When it comes to aircraft ownership and operations, nothing is ever gained by skimping on maintenance, but often much can be lost. We have all heard the old adage "pay me now or pay me later." It's truer than you think. The problem with this concept is waiting until "later" will, more times than not, end up being much more expensive. As you can well imagine, that way of thinking can also have devastating physical consequences.

If you are an aircraft owner, do yourself and your passengers a favor and make sure to review all the inspection and service recommendations for your aircraft and engine with your maintenance provider – today. It is very important in the overall scope of cost of ownership that we keep our aircraft in top condition and having good communications between yourself and your mechanic is the foundation of a good relationship.

Think about all those items we tell the mechanic to put off until a later date. Sometimes we owners just don't understand what these decisions can really mean. Over the course of a few years, assuming none of those items have been repaired, serviced or replaced, you end up with an aircraft that will have diminished value – and diminished reliability.

"The simple fact is, doing things the right way at the right time is really no big deal."

Most potential buyers would shy away from interest in an aircraft with a long list of items requiring service. Wouldn't you? I see people all the time putting off maintenance and care on their automobiles only to find that after a few years, they are left with residual value at best.

The simple fact is, doing things the right way at the right time is really no big deal. And it's cheap insurance towards maximizing the reliability and safety of your aircraft and your passengers.

On behalf of all the employees at Superior Air Parts, we hope these chapters have raised your personal awareness and have sparked some questions to ask of your maintenance provider.

Everyone here at Superior is committed to providing the highest quality and value available in our industry, with the goal of keeping you and new generations flying for many years to come.

## My thanks to you

Thank you for taking the time to read *Engine Management 101*. It is my sincere hope that if you have any questions regarding getting the most out of your aircraft piston engine that you consider Superior Air Parts as your go to source.

I would also like to give a big thank you to Superior Air Parts for their support for this endeavour and making this information available to you free of charge. Our payment will come from you enjoying many years of enhanced aircraft reliability, efficiency and most of all, safety.

Bill


Millennium

**Superior Air Parts' vision and philosophy:**
"To create products and technologies that advance the state of piston aircraft engine performance at an affordable price."

**Superior Air Parts, Inc.:**

## Making flying more affordable since 1967

When Superior Air Parts opened in 1967 they made one part – a replacement valve guide for piston aircraft engines. It was a simple part, but it was made with exceptional care and quality. Superior's valve guide was equal to, and probably better than, the original part it replaced. And it cost a lot less.

Today, the company offers over 3,500 different piston aircraft engine parts in its catalogue, Superior Air Parts is the largest FAA-approved Parts Manufacturer Approval (PMA) producer in general aviation. And every part we make is painstakingly manufactured from the latest materials using the most modern production processes available. These aren't just replacement parts they are very often, improved parts.

The hallmark of Superior's vision to make the best products possible is the Millennium Cylinder family. With nearly a quarter of a million cylinders in service around the world, Millenniums are by far the most popular and trusted aftermarket cylinders in all of general aviation.

Along with advancing technology and manufacturing, Superior is dedicated to holding the line on product pricing. From the company's inception we have delivered more product value at a lower price. Why? Because that's our commitment to our customers.

From a simple valve guide to a complete FAA-certified Vantage Engine™, each of the 3,500-plus parts and components Superior builds, offers the best combination of quality, reliability and value in their respective categories. But, when you look back at our history that's no surprise. That's the way Superior Air Parts has done business for 50 years.

For more information, visit: **www.SuperiorAirParts.com**

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