Aircraft Repair --The Missing Manual

John Schwaner

by John Schwaner

john.schwaner@gmail.com

Otto von Bismarck: 'Fools learn from experience. I prefer to learn from the experience of others.'

Contents

Re: question about oil filter examination

John,

I have read your knowledge base post on oil filter examination and wondered if the author (or other knowledgable person) could answer a quesion for me.
I routinely open my filters. Under casual observation nothing much is evident. The last couple of times I looked a little closer than usual and in bright sunlight. In the bright light I can see scattered microscopic shiny bits. They are so tiny you wouldn't see them other than by their reflection. I have been told that this represents an inconsequential finding, possibly microscopic bits from plating - normal wear finding. Would you agree?

I also find little bits of debri here and there, non-metallic in appearance and non-magnetic. It has the appearance of a tiny quantitiy of sand which may be just what it is.

I have not found anything large, magnetic, or otherwise scary looking.

Ultimately my question I suppose is; Should anything at all be visible on the pleats? I would imagine that filtering oil through there for 40-50 hours your gonna find something. That's what it's there for, right?

Thanks
Steve

On my other web site I mention how to use sunlight to see microscopic particles in the oil. http://www.cancutter.com/how_to_inspect.htm. These might be small bits of bearing material.

Often with mechanics I don't agree with their theory but I do agree with their actions because often it is based on years of practical experience.

It is not normal for parts in an engine to shed metal particles. Possibly during initial break-pin (when you have surfaces getting to know one another) you can have a small amount of particles. From then on normal wear on surfaces does not generate particles. So much for theory. Now what do you do about it?

If the particles are very small and not many then typically the answer is to keep checking and make sure it doesn't get worse.

For your stuff that looks like sand. Try to squish the particles between two pieces of glass or your finger nails. Sand will not squish and will scratch the glass or your finger nail.

By examining the pleats you aren't going to find cam lobe or cam follower material in the early stages of failure. Better to rinse the pleats with solvent and a toothbrush. Drain the liquid through a coffee filter land let dry. Place a magnet under the coffee filter and move all of the iron to one side. If there is enough fuzz sticking to your magnet to cover the end of a stick magnet then inspect the cam lobe and follower. You will get a much better idea as to the amount of stuff that is in your filter using this method.

Re: question about oil filter examination

Thanks very much for your help John.

Here's an update:

In advance of reading your response I actually rinsed off a few pleats into a glass container with solvent.
Note that I picked pleats where small visible accumulations had gathered which I suspect relates to oil flow patterns through the filter.
I then dried the material which consisted of a few very tiny particles of varying color - tan, brown, gray.

None of it is magnetic.

I then took it out and squished it between my fingernails. It all mashes up effortlessly into a fine powder.
My feeling as therefore that this represent tiny bits of carbon or combustion products.
I think the shiny things I'm looking at are microscopic gray carbon bits.

Steve,

Black and gray particles that you can squish between your fingernails are pieces of carbon, sludge and lead oxides and are normal.

Small shiny bits you can spread them onto a microscopic slide and and add a drop of Drano mixed with water. Look carefully under the microscope. If it is aluminum it will start to fiz and dissolve.

Prop strike teardown recommendation

To answer the question "should the engine have been torn down for a more complete inspection"?

My recommendation has always been to do a tear down inspection for the following reasons:

1. After a prop strike there is rightful concern about the airworthiness of the engine. This concern can only be answered by inspection and not by hope, prayer, or opinion.

2. Having a shop that has performed approximately 1 prop strike inspection each month for some 20 years, I still cannot tell you which prop strikes cause damage and which ones don't without an inspection. This has taught me that the preceived "severity" of the propeller strike is not a criteria for deciding which engines should be inspected and which ones need no inspection.

3. I personally didn't tear down my engine after I hit the towbar with the propeller and sent it flying across the airport. But then we did one on a Navajo that hit a plastic caution cone that had damage -

4. Engine mounts can also be damaged. That said, my opinion is based on my personal experience and others have views that conflict with mine based on their experience and judgement. I could be wrong.

I have spend many year pondering how to inspect the engine without tearing it down and I have never come up with an adequate method. Your question as to signs to look for - I don't know.

Removing magnetism from Austenitic Stainless steel

I bought some 304 stainless steel tubing for building a fuel cell and found that even though it was touted as being austenitic, it had a magnetic field down the welded seam (nowhere else). I had tested the tubes with a neodymium magnet and saw where the field was. Will your degausser remove the magnetic field?

The degausser will not prevent the austenitic stainless from being magnetic. It will remove magnetic fields excepting the earth's magnetic field.

Austenitic is slightly magnetic when cold worked. In the fully annealed condition it is non-magnetic.

Any austenitic (300 series) stainless steel which is magnetic can be returned to non-magnetic condition by stress relieving to 700-800 degrees C. It then reverts back to its fully annealed condition and is softer and weaker. There may be other issues with annealing so the best thing to do would be to engage a metallurgist.

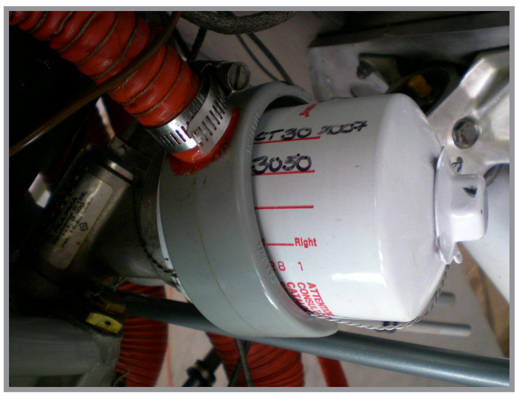
The degausser will remove an artificial magnetic field from a iron object, leaving just the earth's magnetic field. By testing with a magnet you have probably slightly magnetiized the weld area (stressed area).

High oil temperature in Lycoming and Continental engines

Hi John,
Here are the photos of my home made oil cooler for the Continental O-300. It actually takes about 15 degrees out of the oil on these hot summer Texas days.

Take a close look. This is a Rapco vacuum pump cooling shroud!

This customer installed the Rapco vacuum pump cooling shrould around his oil filter. Neat idea and it reduced oil temperature by 15 degrees!



Degauss Mooney

Big John,

I've got an old mooney that I cant get the compass to compensate even close. Will your rental degausser work? If so, I need to rent it. Also, any tips or instructions for the best job possible? Please let me know.

The degausser will eliminate artifical magnetic fields in metal structures. If that is your compass problem, then yes it works very well.
The concept of the process is to use a meter to identify the field location and then use the degausser to eliminate it, and then use the field to verify the effectiveness. Very easy,

quick.
In order to prevent shipping the equipment and attempting to use it for other types of problems, you need to verify as well as possible what is causing the problem. For instance, your tac uses a rotating magnet. It is possible that the tac cable where it enteres the tac is magnetized. If this cable end is within 3-4 inches of the compass then it will pull on the compass. A Bendix or King VOR head that is within 3-4 inches will also pull on the compass.
The degausser also has no effect on natural magnetic fields radiating from close-by iron parts. For example, all pieces of iron have the earth's magnetic field in them. This field radiates out from the iron in a different direction than the earth's field traveling through air. So any iron object in close proximity to a compass will pull on it. That is where the field indicator helps, It is too weak to detect the earth's field but strong enough to detect any stronger artifical field.
Natural fields are usually not a problem and that is what the adjusting magnets in the compass are designed to correct. A quick check to see if that piece of iron has an artifical field is described in the link below but basically consists of attaching two metal paper clips together so one dangles from the other and see if they are attracted to any iron objects within a few feet of the compass. Check out my web page. http://www.sacskyranch.com/degauss.htm .
If after doing some checking as described above, you feel that the degausser is the answer to your problem, then the rental is $75.00 plus freight.

Bendix D3000 magneto redundancy

John, I purchased and read your magneto book, which I found informative and interesting. After reading the book, I do have two questions I'm wondering if you could answer given your experience with magnetos.

1. Our Cardinal has the dual magneto, although I am considering a conversion to a non-D at the upcoming overhaul. My question regards redundancy: what internal elements are common to the two magnetos within the D housing?

Do they only share a common drive shaft (and gear), or are any other electromechanical components shared - e.g., cam, magnets, etc.? Do you know of any source where I could see internal photos or mechanical or cutaway drawings of the D3000 magneto so I could better understand its design?

About the only parts that are truly redundant is the coil, points, and capacitor.

The D3000 magneto is a good magneto, easy to work on and reliable. Like any device it has its limitations. The following three areas should be well understood, respected and maintained, as all have caused fatal aircraft accidents:

- Impulse coupling spring (part number 10-51324)
- Hold-down clamps
- Cam retaining screw

Impulse Coupling Spring:

Breakage retards timing causing complete loss of engine power. Cessna 172N N738BC ditched at sea with 2 fatalities. On any magneto the impulse area sometimes gets rusty from condensation. The impulse spring gets tiny rust pits that create stress corrosion cracking. There is no warning - it just breaks. With two magnetos you lose timing but you can turn the bad magneto off; with the D3000 magneto the broken spring retards the timing on **both** magnetos and you lose power.

Follow TCM's instructions and recommendations to the letter in regards to inspecting and replacing the impulse spring. Personally, if I lived in a corrosive area I would replace it every year.

Hold-down Clamps:
See my article at http://www.sacskyranch.com/eng410.htm

Cam Retaining Screw: *"Everything hangs on this connection"*

Here is a copy of an email I received some time ago from Germany:

A pilot came to an aircraft workshop with the problem,that the engine did not start well and did not reach more the 2200 RPM. (Cessna 170 N engine Lyc.O-320-H2AD SNR L-8408-76T)

The workshop made -a test run on ground:

the engine rpm drop was 120-130 rpm.-
The different pressure in the cylinders was 1.)80/78; 2.)80/79; 3.)80/78; 4.)80/77.-
The intake tube of the Cylinder No 3 was leaky -it was renewed.-
The timing of the ignitions examined and adjusted.-
The air intake filter was dirty and cleaned -
The following ground check did show no problems: rpm drop 70-80 rpm max rpm 2320 rpm.

After this the aircraft made a take off and crashed immediately in the ground, as the engine lost power*.*

The investigation did show, that the screw (Fig 1-14 D-3000 Magneto manual) was loose

and so the cam breaker could turn on the cone.

The problem here is that the mechanic did not order a new cam screw and re-used the old one. You loosen this screw when you adjust internal timing. This screw is a self-locking screw that uses a nylon patch on the threads. The locking effectiveness is poor if re-used. Continental says to replace it with a new one. Follow the factory instructions - accept no deviation or alternative methods of compliance.

Continental (Bendix) has addressed each one of these areas in their maintenance manual. Personally, if the mechanic did not have the maintenance manual for the D3000 in hand I would not let him touch the magneto.

There is an interesting discussion of this screw and the problems associated with installing it that I highly recommend be read by anyone working on this magneto. http://www.aaib.dft.gov.uk/cms_resources/Mooney%20Aircraft%20Corporation%20M20J, %20G-EKMW%2011-06.pdf

Oil Filter Examination - continued

John,
So, being a reformed lab-rat myself, I set up a little scope and had a look at my filter washings. Here's a little show if you have a minute to view and comment. I realize there are services that will do this and I will likely send the next filter to them to see what they say but I thought you might like to see what I came up with...Incidentally, under magnification, most of the tiny reflectivity's I was seeing on the filter in the sun represented light reflecting off of oil dampened flat surfaces of a variety of tiny non-metallic looking debris. My stereo scope:

I washed one half of the total available oil filter, after cutting it out, with solvent into a cup.For reference, the cup's base diameter is about 1.5 inches.Here's all that I got in washing:

Under magnification it looks like this (20-40X)

I threw in a hair (ouch!) for reference:

The vast majority of the material appears to be non-metallic junk (silicates, carbon, or whatever). I was able to see only a couple of very tiny magnetic bits using a magnet. You would never have seen them move with the naked eye. I next did a trial of drano with some aluminum filings so I'd have something as a reference. Bubble and fizz as advertised.I then applied the drano solution to the washings. I was able to locate only 2 or 3 microscopic fizzies out of the whole lot. Not much aluminum in there. What is notable, and you can see it in the photo immediately above, is that there is a scattering of metallic looking particles (red circle).These are mostly the width of a hair and smaller. They are not aluminum and are not magnetic. They have the appearance of microscopic bits of aluminum foil as you can see.Plating of some kind? Any thoughts? Know anyone crazy enough to look at their filters this closely?

I hope your not tiring of this! A little more... Re-reading your metals analysis post, I proceeded to look at the effect of HCL on the debri.I tried 25% HCL first with very little observable effect. I then went to 100% HCL. At this concentration, the tiny shiny bits were clearly seen to bubble and begin to dissolve. No green tinge was seen anywhere so I doubt chrome. There is no blackening seen either. Based on your post, I'm guessing tin. So, I would characterize this as scattered, microscopic platelets consisting of tin. Question is, is this a matter of concern or a normal wear finding? Any opinion? As I said, I will send the next filter out and see what the professional lab has to say.

I thought this was a professional lab! Your microscope looks familiar - just like mine! A good bench microscope is a handy shop tool. Now that I'm older I use it to read tiny part numbers off of parts.

Your sample looks very clean. If you have blow-by of combustion gas past the rings, the sample will be darker with more flakes of black carbon. On turbocharged engines the filter paper will be almost black and brittle.

What I used to do was to squish all of the debris between two microscope slides. If it squished with no scraping sound - good - no sand or rocks. If it scraped, scratched, and made noise then I had some sand particles - time to check the induction system for leaks; or stop pulling out the alternate air door on run-up if the runway was dirty!

If your tiny bit of shiny metal is brittle then suspect chrome, otherwise tin if it passes the drano test. Either way one microscopic bit is not important.

I would use a stick magnet to collect all of the bits of iron. Usually they were not shiny and looked like iron filings that you collect from dragging a magnet in sand. If they encircled the tip of a stick magnet then there was cam or cam follower problems. If less, then everything was OK.

Leaning a Carbureted Lycoming or Contintal past Peak

If your objective is to lean of peak (LOP) then lean until the engine gets rough. However, I see no purpose for this. First outline the problem and the solution:

1. operate at best power to climb over that mountain, or maximize speed, or, 2. operate at the lowest specific fuel consumption to maximize range and minimize $, or, 3. operate the engine in a manner that minimizes lead deposit build-up.
Objective 2 just happens to be somewhere on the backside of an egt curve. Objective 3 is indeterminate as it depends on the engine and power setting but as a general rule leaner is generally better up to a point.
If your objective is 2 then very SLOWLY lean until you feel a slight roughness and then

enrichen slightly to remove the roughness. You are probably very close to lowest specific fuel consumption. So how does this relate to LOP? At least one cylinder is LOP. EGT readings show some cylinders somewhat hotter egt (closer to peak) or somewhat lower egt (before peak, or after peak). All very confusing display for the pilot and somewhat worthless data.
To add the the EGT confusion, there is no standard temperature drop past Peak EGT that produces the leanest operation without engine roughness. And it is engine roughness that limits lean operation, not some exhaust temperature reading. So lean to engine roughness and then enrichen slightly.
engine roughness defined for this purpose: A very slight and non-regular vibration pulse that your passenger probably won't notice. It is NOT a "rough engine"
All leaning suggested above is at power settings below 75% power.

I have this problem with my aircraft engine...

Thankyou for your inquiry regarding your aircraft engine. It has been over 15 years since I sold my engine overhaul business and I find my knowledge is dated and sometimes fading from memory. Even though I cannot answer your specific question, I would like to express my thoughts on airworthiness that might be of some help.
In the aviation industry airworthiness is based on objective evidence. This standard exists in most countries and is exemplified by the use of "inspectors" and "documents". Your question about the "airworthiness" or safety of your engine is a valid question and you do not need a reason to ask. In fact, inspector's will pull job sheets at random and ask for proof of airworthiness. Inspectors and inspection based on documents are an integral part of aircraft maintenance at every level.
How does your mechanic, maintenance shop, manufacturer, etc. show airworthiness? All of the following are typically required:

- Evidence of approval from governing body,
- Evidence of training,
- Necessary tools and equipment at hand,
- Appropriate maintenance manuals,
- Calibration reports to show measurement integrity,
- Inspection reports and check sheets,
- Functional tests.

Objective standards of airworthiness are not based on a "personal" relationship between inspector and technician. In fact, this often hinders the objectivity of the inspection.
Your question involves a measurement issue. This can only be answered objectively by either:

1. obtaining the inspection reports showing dimensional recordings, with calibration sheets to back up measurement quality.
2. Re-taking the measurements.

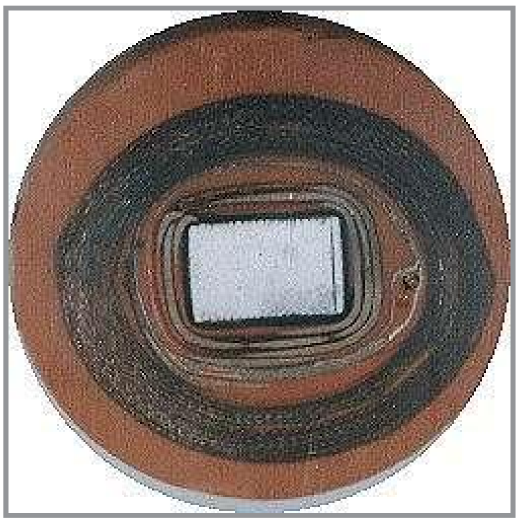
The burden of proving "airworthiness" rests on the shoulders of the maintenance facility. Generally, there is a record retention time limit for such questions to be asked, often 3 years or longer.

If it's not broke - don't fix it

God I hate that saying. It's right up there with the pilot telling me "it will be OK. I'm in a hurry and gotta go."

The I-35W bridge that collapsed into the Missippie river and killed 13 people was operating fine the moment before it collapsed. It had failed previous inspections and was rated as "structurally deficient". These inspections were ignored because it was operating fine. Operating fine - don't fix it or "if its not broke don't fix it - kills innocents.

Inspecting the magneto coil



I received this email inquiry:

John, Recently we have found, during a 500hr Slick Mag Inspections, defective coils. The engines in both of these cases were running OK when brought in for the inspection. When coils were tested found primary coil to be within tolerances but the secondary coil showed open resistance. In both cases we replaced coils. We just want to understand why the mags were still operating so we can give an "intelligent" answer to the customer as to why we had to replace coils when all seemed to be operating fine.

Cross-section of Slick coil. Large primary windings next to core. Smaller secondary windings on outside.

Interesting question as sometimes inspection standards seem arbitrary without an explanation of what their intended purpose. by "open resistance' I assume that you had infinite resistance or a open secondary circuit.

Your ohm meter does its check by flowing a tiny bit of current through the secondary wire at a fraction of a volt. Any broken wire will stop the current flow and indicate an open circuit. However, when the engine is operating the voltage in the secondary wires is high enough to jump a spark plug gap so it will easily jump across a small break in the secondary wire inside the coil and the magneto operates fine - for awhile.

The arching inside the coil causes the coil to get hot. On a high-voltage coil tester when you pick the coil up it's like a hot potato! The burning inside the coil starts to melt insulation and burn the secondary wires. Gradually the number of secondary windings reduces as the current shorts across adjacent wires. Now the ratio of primary windings to secondary windings is reduced so the transformer effect of stepping-up of voltage is reduced.

The first indication for the pilot is hard starting; at the slow rotation speed during start there is not enough voltage to spark the plug. Get it started and it runs fine for awhile as the high rpm creates enough current in the primary to off-set the degradation in the secondary. Eventually, the burning inside the coil reaches the outside by burning a hole out through one end of the coil.

It is amazing when you see this because you know that the aircraft was operated with all that internal coil damage. Eventually, enough secondary wires are damaged that the magneto won't produce enough voltage to fire the plugs. At that point the aircraft is grounded in some hole-in-the-wall airport with an angry wife and screaming kids.

Checking secondary resistance on a Bendix S-1200 series magneto

Editorial on inspections: The I-35W bridge that collapsed into the Mississippi river and killed 13 people was operating fine the moment before it collapsed. It had failed previous inspections and was rated as "structurally deficient". These inspections were ignored because it was operating fine. Operating fine - don't fix it or "if its not broke don't fix it - kills innocents

Sealing Aircraft Engine Cases

John:

The sealing of engine cases seems to come up on aircraft groups often. Lycoming says to use POB #4 and some other materials. I have tried to ask question about where to purchase these materials and cannot get an answer. Some people say it is made by Perfect seal, and some say Permatex. Could you clearify this and show where and how to use these materials in a section? You could have pictures showing the thread and showing how much of the sealant is put on these areas.

Don,

I am reluctant to discuss crankcase sealing as my method (the traditional method) conflicts with both Lycoming and Continental. The way almost all overhaul shops did it 50 years ago is time proven - Titeseal and silk thread.

The Titeseal (usually medium weight) is used only to provide a tack surface for the thread; it does no sealing in itself. Thus the line of Titeseal need not extend completely across the surface, just wide enough to lay your thread. It should be absolutely thin.

The silk thread that Continental sells is the correct diameter (gage?) as too large a diameter will make a small divot into the crankcase parting surface.

The one problem with this method is that it's slow and large shops or factories think it takes too much time. They would rather slap some goop on the surfaces and torque it up.

Why Titeseal? It remains tacky so you have unlimited work time to lay down the thread. It doesn't cure into small balls or particles that can plug an oil passage (usually the oil passage through the rod bearing - only a few thousandths clearance). Also, Titeseal is a great NPT thread sealing compound so it has another purpose in the shop.

A possible shortcoming of silk thread is that silk thread is not tolerant to damaged or scored parting surfaces. I might consider a more elastic product when working with damaged faying surfaces.

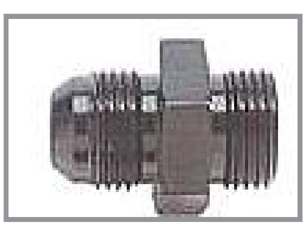
Whatever method is used you have several objectives:

- Thin is better as it retains the clamping force produced by torque. Thick gaskets or fluids that compress will loosen the joint and cause all kinds of problems.
- Anti-creep. Product should not "run away from stress" i.e. it should be anti-extrusion and anti-oozing for the same reason as above. This eliminates many of the RTV style sealants unless applied extremely thin.
- Product should not be capable of contaminating system. This eliminates RTV style sealants.
- Product should be easy to remove at next repair.
- Product should not create corrosion.

"The mark of an expert is decidedly not a big wad of hardened silicone out of every joint, but proper preparation of sealing surfaces." Greg McConiga, Motor Service, Feb. 2002.

Silk Thread part number from Continental: 641543
Titeseal is available from most aircraft parts houses. Lightweight titeseal works well on gaskets to keep them from leaking. Doesn't harden so the gasket removes easily during later repairs.

Bastardized AN fittings - Which AN fitting goes into the hole?



Automotive racing has adopted the aircraft AN fitting technology, bastardized it, and now sent it back into the aircraft industry. I've talked about the differences before in my article "What is the difference between aircraft AN and JIC fittings". The result of this bastardization is confusion and extra expense for the aircraft industry. Let me try to clear up some confusion when it comes to screwing fittings into

straight-thread ports.

In non-aircraft applications ports are mostly straight thread "ORB" O-ring Boss. The automtove industry (heck I don't know what to call you guys - "race industry", is that better) has plenty of adapters to adapt AN to the port - pictured below. There is no AN number for this adapter. It does not exist in the AN series - for good reason - it is not needed in aircraft. In aircraft, the traditional straight threaded boss is called a "AND" port (AND10050 or MS33656) and doesn't require an adapter fitting. This should be the end of the story for us aircraft people but it isn't.
Some automove style components with ORB ports are being used in aircraft. These require the adapter shown above. So now us aircraft people must be able to look at the port and tell what kind it is.

Is it a tapered pipe thread port (NPT), an ORB port or a AND style port? Curse you automotive people for bringing us your ORB crap! NPT is bad enough!

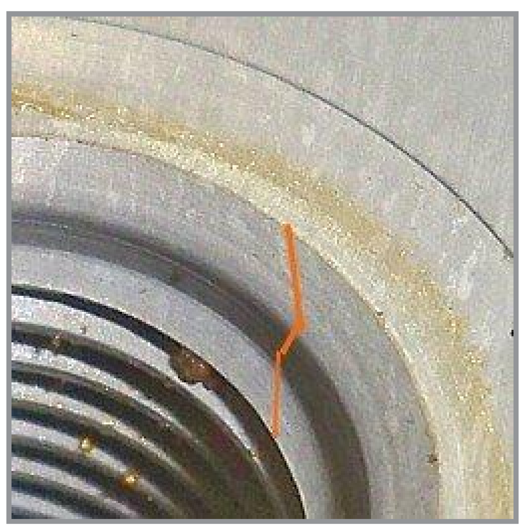
Here is a aircraft brake caliper with a male AN nipple sticking out of the port. It looks like out adapter above. But it's not. Here is a picture of the entire fitting.
Notice that this is a standard AN fitting. Below is a picture showing how it installs with a boss o'ring.

Simple, just install a a boss O'ring onto the end of a standard AN nipple fitting and screw into the port. You can also use a bulkhead fitting and special nut for high-pressure hydraulic applications.

Here is a picture below.
This port (AND10050 - MS33656) has stronger (greater shear strength) threads (class 3 versus class 2). and can accomidate the extra length of the nipple. It is adaptable to a wide range of AN fittings and pressures.

AN fittings that can be screwed into AND ports are what the drawing calls a Type E style and can be used to seal on the flare OR seal on the nut with an O'ring. Not all AN nipple fittings are Type E. Below is a non-type E fitting. Notice that there is no nut hex and no circumferal groove above the last thread. If you wish to use a Type E angle fitting then use the bulkhead series with a nut. You can now point the fitting any direction you wish.

What does a AND10050 port look like?
A AND port has a countersink around the top edge forming a 120 degree included angle. This port is also sometimes called a "Military Straight Tread Port". The latest drawing for this port is AS5202.



Use of crush washer on AN Fitting Connections

An "aluminum crush washer" or conical seal is sometimes placed between the flare surfaces. These are mechanic band-aids to be used when you have a leaking connection and no replacement fittings. The usual problem is using a new hose fitting against an old male nipple whose sealing surface has been damaged. It's easier to drop a conical seal into the hole than to replace the damaged fitting. Going back 10-15 years no one had ever heard of them.

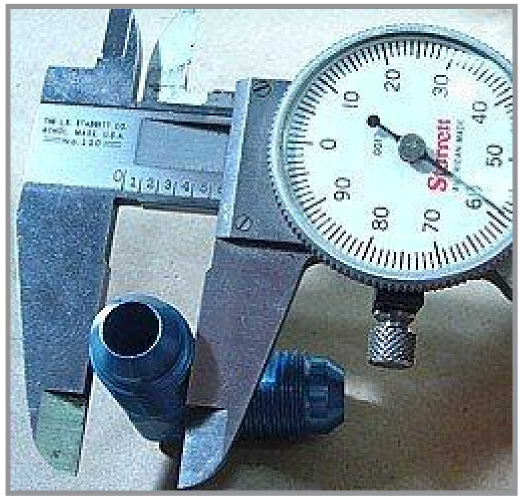
Conical seals getting more popular now, in my opinion, because of the increased usage of steel on steel mating surfaces. Traditionally, AN plumbing mating surfaces were aluminum to aluminum or steel to aluminum. To seal any surfaces, one or both surfaces must conform (yield) slightly under pressure to seal any microscopic gaps between the surfaces. It helps if one or both surfaces are relatively soft. The more recent switch to steel on steel requires increased nut torque to get the two hard surfaces to yield sufficiently to seal. This should not be a problem with good surfaces and proper torqued.

AN Thread Size and AN Fitting Size Chart

Measuring Inside Diameter Measuring outside "major" diameter

AN Dash Size Chart

AN fittings differ from commercial threads in that they are class 3 instead of class 2 and generally UNJF rather than commercial UNF. Threadform: UNJ -3A or 3B Note: There is an entire industry supplying so-called "AN" fittings that do not meet aerospace standards. See my article at http://www.mechanicsupport.com/articleStronger.htmanicsupport.com/articleStronger.htm
Web App version of this chart. Bookmark the link below in your mobile device:
http://www.mechanicsupport.com/apps/Threads/index.html
Dash and Thread Size Chart Click on the Right button for next chart. Handy reference for sizing fittings and fasteners.



Dash Size	Tube Size	Thread Size	Male Thead O.D.	Female Thread I.D.
2	1/8	5/16	0.31	0.27
3	3/16	3/8	0.38	0.34
4	1/4	7/16	0.44	0.39
5	5/16	1/2	0.50	0.45
6	3/8	9/16	0.56	0.51
7		5/8		
8	1/2	3/4	0.75	0.69
10	5/8	7/8	0.88	0.81
12	3/4	1-1/16	1.06	0.98
14	7/8	1-3/16	1.18	1.11
16	1	1-5/6	1.31	1.23
20	1-1/4	1-5/8	1.63	1.54
24	1-1/2	1-7/8	1.88	1.79
32	2	2-1/2	2.50	2.42

Hose Problems

Hose Problems

Yesterday a friend brought by some hoses off of his racing car for pressure testing. Normally, I only do aircraft hoses, but for a friend --OK

So the hoses fail. Look carefully at the hose to the left and you can see that the hose pulled out of the socket. The hose was only engaged into the socket 1/4 inch or so. This is why he had a hose leak - it wasn't assembled properly to begin with.

Of all the different types of aircraft hoses I build, this style is the most tricky to assemble correctly. It is also the style of hose that race-car and custom car builders love to use. We use very little of this stuff on aircraft and in general don't like it - except it is "pretty" so I guess that is all that matters. There are multiple ways you can get into trouble screwing the fittings onto this style hose. Here is just one tip:

After you screw the hose into the socket to the correct depth, place a "back-out" mark on the hose. Then when you screw the fitting together go back and make sure the hose hasn't pushed out of the socket as you screwed the nut-nipple Assembly into the socket.

Also, don't flood the cavity with oil as you can create a hydraulic lock that prevents the rubber from sliding into the recess.

Here is a link to another article on hose assembly at my web site:

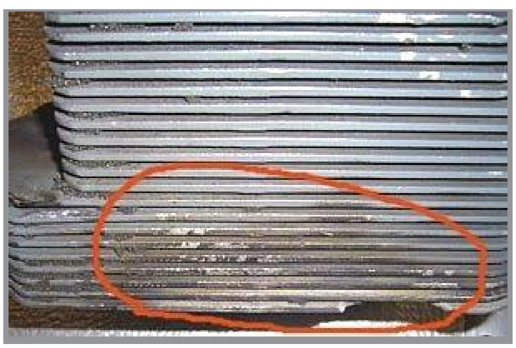
http://www.mechanicsupport.com/aircraft_hose_assembly.html

AD2009-16-03 SAP Cylinder Cracking

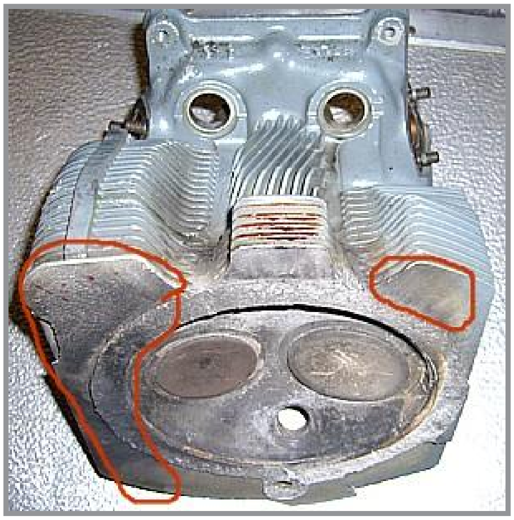
AD 2009-16-03 results from reports of cracks in the area of the exhaust valve and separation of cylinder heads from the barrels of SAP cylinder assemblies with certain part numbers.

So now 8,000 of you (8,000 engines effected) need to inspect your SAP cylinders for head cracks per AD2009-16-03. Two inspection methods are presented in the AD:

1. Visual inspection for combustion staining, and
2. Pressure test.



After spending 30 years running a cylinder overhaul shop I learned one thing is certain: cylinders crack. No surprise here. Cracks in aircraft cylinders are not limited to any one manufacturer - all have had problems with cracks and will continue too given the hard work we ask of them. So even if your airplane is not directly affected by this AD, checking cylinders for cracks is important and can be incorporated into your normal inspections without much additional time or expense. Lets discuss both of these inspection methods and introduce a third method of my own making: Both inspection methods presented in the AD only detect cracks that extend completely through the wall and large enough to pass gas. That is one big crack and on the verge of outright fly-apart fracture. Lets look at a cylinder for what it is: a pressure chamber that gets pressurized and de-pressurized with very hot corrosive gasses 20 times a second. If a flight is 1 hour long you have one "thermal cycle" but 72,000 pressure cycles! **Pressure test:** There is nothing unusual in the requirement that if during a compression test, gas is leaking from the pressure chamber (and it's not going past the valves, and, its not going past the rings) then you need to start looking for cracks in the cylinder head. Well that's something you should do anytime you suspect your cylinder has a hole in the head and won't hold air. Only inconvenience is you have to do a compression check each 50 hours per the AD. **Staining Inspection ("black combustion leakage")** This inspection is much more interesting and anyone can do it with just a mirror and small flashlight. Pressure Vessel Breach The picture above shows staining from gas leakage out a crack in a Lycoming



cylinder. At each 50 hour oil change you can look at the fins for staining. It just takes a few minutes of eye-ball time. This crack didn't get detected so lets see the end result:

So there you have it - spontaneous cylinder head separation. Notice the gas staining in the red circles. There was plenty of advanced warning. Inspection for exhaust staining on the outside fins of a cylinder should be a normal inspection item.

Gas Staining - pressure vessel breach

Lets take a more hidden example: See anything wrong with this O-200 cylinder below? Well, you're not going to at this angle. You're not looking at the right angle nor in the right places. There's gas leakage and a crack right there between the yellow lines. Here is how you should look at the cylinder - look between the fins! That's where the crack penetrates - not at the end of a fin but at its base. Same cylinder but different view: See the dark staining between the fins. Do you see the crack? Back in the 1980's we did some experiments with gas or oil leakage, especially leakage between the barrel and head. We'd take cylinders that had oil and

gas stains and pressurize them with 80 pounds of pressure to see if they leaked. Our experience was that they didn't leak in our test. Certainly if the crack is large enough and open it will leak but cracks like the one above would not leak air when pressurized. Our theory is that our test is at room temperature without the strains induced during the actual combustion cycle. Only cracks at their last stage - when they're big, large, and about to come apart, leak gas. So the compression test and soap and water is the final frontier - gas and oil staining come first. There is another test that we used and that is the ping test. Here is how it originated: I got upset spending shop time cleaning cylinders and then checking them for cracks only to find out after 2 hours of labor that the cylinder was no good. Better to find the obvious crack before investing any shop time. Once a cylinder passes the ping test then we would further clean and inspect for less obvious cracks. Take your finger nail or the plastic end of a pen and ping a cylinder fin. It should ring. If it goes thud then there could be a crack at the base of the fin. You can even take your pen and just stroke it down the cylinder head. The link below is a sound file so you can listen to the sound a crack makes! This doesn't work for fins that are in contact with baffling, they have to be free to ring like a bell. Here is the sound **Additional Information:** I have a E-Book available (windows only) at my web site that you can download called "Crack Detection Using the Unaided Eye" Visit my

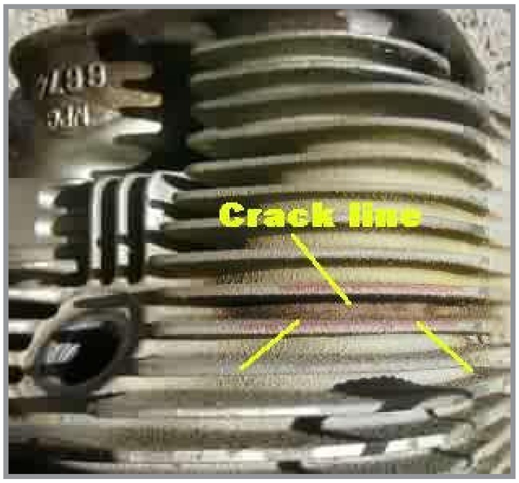
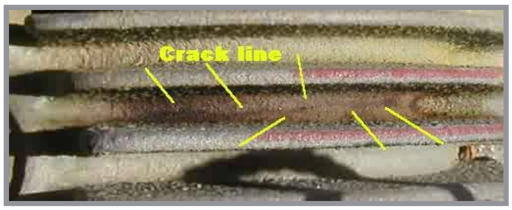
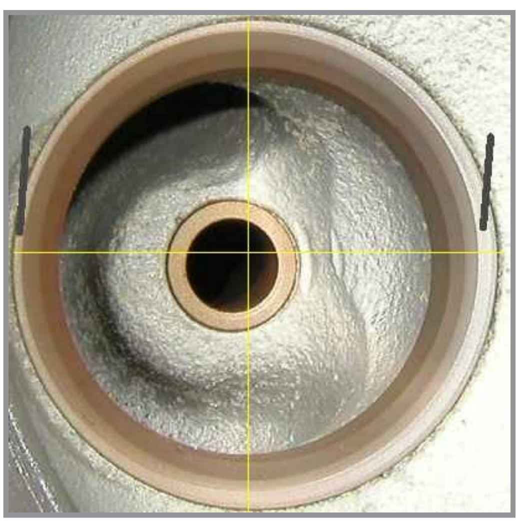


photo albums for more maintenance pictures Visit www.mechanicsupport.com for more articles and software for mechanics



Bad Valve Seat Job



Bad valve seat workmanship stands out like a sore thumb if you know what to look for.

The first think to look for is the alignment between the seat and the guide. Are they concentric? In other words do they have a common center? In our picture below notice that the center of the circle formed by the seat is not centered to the circle formed by the guide. The circles are eccentric.

What I'm looking at is the thickness of the top of the seat at the black lines. Notice the width is thicker on the right side than on the left side. Of course a face must be ground into the seat before you can check concentricity. What happened here is that the seat grinder pilots from the guide so it wants to align itself to the guide center. This causes the grinding stone to grind more on to the left in this picture. If the seat and guide were concentric then the seat grinder would grind dead-center and there would be equal widths.

The practical effect here is that the stone pressure is mostly on the left where it is doing most of the grinding. Now drop a valve onto this seat. Just like the grinder, most of the seat contact pressure will also be on the left side. In analyzing eccentric seats in aircraft engines we found that they develop exhaust valve leaks at the narrow side. This makes sense as the narrow side is where the least amount of contact pressure occurs. Also, the valve is slightly tilted to one side. I would also presume that guide wear would be accelerated as the valve stem pushes into the side of the guide as the valve attempts to center itself onto the seat. No fancy 3 angle valve job is going to correct this seat.

What do you do about it? The only think you can do is move the holes back into alignment. This requires fixtures and cutters and cannot be done with hand tools. Also, to move a hole one must make it larger. You come up against maximum oversize limits quickly when you start moving holes.

Cessna 152 Poor Idle - Carburetor Foam and Hollow Floats Sb-2

A quick tip from one of our customers who services a small fleet of Cessna 152's. Rough and poor idle can often be corrected by:

- Each 100 hours pressure testing the intake and exhaust system to find air leaks.
- Make sure carburetor float is working properly.
- Working on the carburetor won't make the engine run any better if the problem is an air leak in the induction system.

This is the newest Volare foam float. You can purchase these from www.sacskyranch.com or call 800-433-3564

Below is a link to the Volare Service Bulletin

volare Foam Float Service Bulletin SB-2

This is the old style float. Notice that the float is half filled with fuel!

Fuel Hose Installation and Electrical Wiring in Aircraft AD2009-15-01

I was blown away by this Airworthiness Directive 2009-15-01 on HAWKER BEECHCRAFT CORPORATION G36 "the next generation Bonanza". To quote:

This AD results from reports of chafing between the wire harness/connector(s) and fuel line. We are issuing this AD to detect and correct chafing between the wire harness/connector(s) and fuel line. This chafing could lead to fuel leaking into the cockpit and fire in the cockpit if wiring arcs through the fuel line. One report indicated arcing from a chafing wire harness burned a hole through the fuel tube.

A fuel line in the cockpit resting against an electrical wire bundle? Makes me shudder in fear!

For all of you building homebuilt aircraft, here is a very safe, simple and sensible standard for installing aircraft hose and electrical wiring:

MIL-W-5088L Wiring, Aerospace Vehicles
Wiring shall be supported independent of and with the maximum practicable separation from all fluid-carrying lines, tubes and equipment.

Where this routing is not practicable, the wiring shall pass below the lines at an angle rather than parallel to the lines.

Wiring shall not be attached to fluld carrying lines, tubes and equipment unless they require electrical connections or their separation is less than two inches, In areas where separation is less than two inches, the wiring shall be installed to maintain positive separation of at least .500 inch.

There is more in the mil-spec but this about sums it up; don't place a fuel line against an electrical wire bundle. Chafe protection is just a delaying method and does not provide positive and long term protection.

Rough Engine on left mag - nothing you do fixes the problem!

O-320 Lycoming won't run on left magneto

Nothing you do will fix it. Mag check -- engine coughs and sputters on left magneto.

- Replace magneto - still rough

- Check ignition harness - checks fine - still rough
- Replace "P" lead - still rough

So lets replace the harness "just in case" -- Success engine runs fine. 10 hours later problem returns!
One other item interest; can't lean engine, as soon as the mixture is pulled back the engine sputters.

So what's the solution?

The big hint here is the mixture control. It points to the carburetor and only the carburetor. But why just on the left magneto? Lets say you have crappy fuel atomization and fuel distribution. Not real bad, but just bad enough. With two spark plugs firing it ignites a leaner mixture and the engine runs fine. But lets impar the ignition system slightly by weakening it. Turn off 1 magneto and now try to ignite the mixture - it can't do it as well and the engine coughs and shudders. Lean out the mixture just slightly and now even with sparks flying out of two spark plugs it can't ignite the mixture every time. It misses a few strokes then enough fuel has gathered that it ignites and burns and then the cycle repeats. The carburetor nozzle was replaced and now the engine runs fine.

More Magneto Ignition Troubleshooting Tips

Start with the easy and inexpensive and work your way from there. The spark plug should be one of the first items you check. A spark plug resistance check is a fast and easy method. You will need an inexpensive ohm or multi-meter.

Spark plug terminal well showing arching lines. Plug lead is arching to ground by way of the plug metal shell. Replace plug. At the bottom of the well there is a contact. Check spark plug resistance by placing 1 end of the ohm meter lead to this contact and the other end of the lead to the center electrode on the firing end of the spark plug. Resistance should be 800 to 1200 OHMS. Replace any plug above 5000 OHMS.

This is what the resistor looks like inside a Champion REM40E spark plug.

One reason why not too drop spark plugs and a good reason why to carefully inspect the terminal well (shown here) for cracks.

More causes of rough engine

Stuck Valve Check - Quick, Easy, Inexpensive

"Anyway, about an hour and 15 minutes in to the flight, I felt a barely discernible roughness, and then a significant cough, and the RPM dropped about 200. I quickly pulled the carb heat out, but then it got even worse. So I pushed the carb heat back in, waited for a minute, and pulled it back out. My engine was still running, but my RPM I am inclined to think that I was experiencing a sticky valve problem. What do you think John? "

Here is one of my favorite checks as it is fast, easy, inexpensive, and works quite well as I tested it for years in the cylinder shop. I would suggest as part of your compression test you remove the rocker covers and with your two thumbs pushing on top of the valve - pop the valve open and shut. You will feel any dragging if the valve is sticking. If the guide is really worn you will feel two thumps as the valve face closes onto the seat first on one side and then another

There are so many possibilities that only a systematic troubleshooting process will reveal the answer. The O-200 normally is rare to stick the exhaust valve since the original guide material was relatively soft aluminum-bronze. As deposits build-up in the guide, the valve would just wear away the guide. Then Superior had a great idea, use the harder ni-resist guide that the bigger engines have to give better wear - well yes, except now the valve sticks. I'd rather have it wear. It's been so long since I've been in the cylinder repair business that I don't know who is using what guide.

Do not fly if you suspect a stuck valve. If the valve sticks closed and doesn't open in 1/2 propeller revolution the rocker arm supports will blow-off leading to total loss of engine power. Even if that doesn't happen, with each revolution the high opening forces are smashing your camshaft lobe flat. This is why I do not recommend Marvel Mystery Oil and other solvents to fix a sticky valve - yes they might unstick it in time but while it's doing it's work you risk expensive and dangerous engine damage. Also, the root cause of valve sticking is not corrected. A O-200 engine should not stick valves - if it does then something is wrong with the engine (could be the shape of the exhaust port).

Camshaft lobe damage. Trying to push open a sticky valve smashes the camshaft lobe ($$$).

Should you pump the throttle on a carbureted engine?

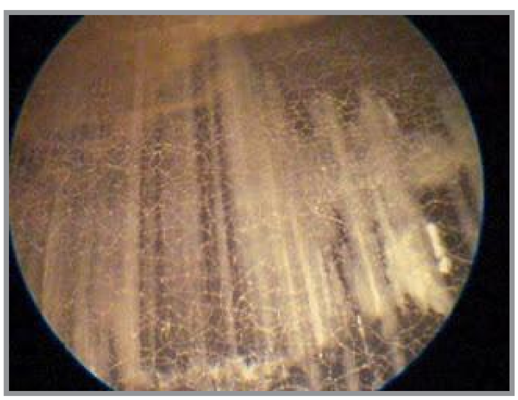
I'm a CFI and have always instructed my students not to pump the throttle when starting a carbureted engine. A recent discussion between one of my students and another CFI has me wondering if I telling my students bad info concerning the accelerator pump on carburetors.Can you confirm any reasons why it's either bad or OK to pump the throttle during start?

Sounds like one of those questions that generates lots of differing views, so here is mine: There is nothing worse than sitting in a burning airplane way out on the ramp without a fire extinguisher.
Our carburetors in flat Continental and Lycoming engines are up-side-down meaning that the fuel has to go up hill to get to the cylinders. Fuel squirted into the intake system just flows back down into the air box unless it's being sucked up into the cylinders. Too much fuel dripping out of the airbox can catch fire as my two personal experiences attests.
So just pumping the throttle with the propeller stopped is only useful for washing out the air box with fuel. In my C-182 it might be necessary to pump the throttle on a cold morning to keep the engine running - but only a little bit as too much pumping and the fuel starts draining back into the airbox - better to use the primer, if equipped.
So to sum up my recommendation:

- *Don't pump the throttle on a stopped engine*
- *Avoid pumping or pump as little as possible*

With that said, that is based on my limited experience. Some might have better recommendations that I would be interested in hearing.

Do Aftermarket Oil Additives Reduce Wear Metals ?



John, I have to say that I'm really impressed! You are right on both counts! It was oil streaking in the bottom of the aircraft cylinder, and this was the first sample since I started using XYZ oil additive. I've never been a believer in oil additives before, but all the reading I've done says that XYZ helps protect engines that don't fly a lot. I don't think that the additive has anything to do with the metals being high, as they were high before I began using it. I'm almost to an oil change, so will be interested in seeing what they do this time.

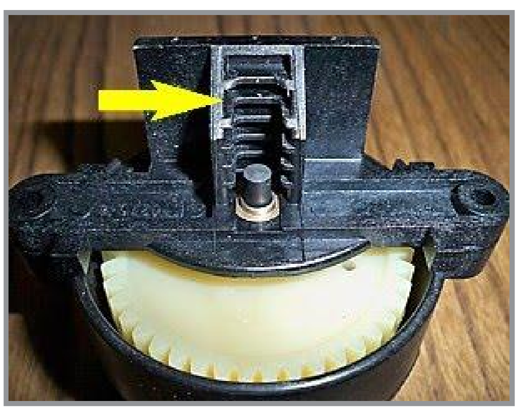
Customer picture below taken of a chrome cylinder barrel through a boroscope with oil streaking. Notice the wavy little lines (channels).

I wouldn't use metal ppm (oil analysis) to make a judgement on the effectiveness of an EP (extreme pressure) additives, such as phosphorus in aircraft engines. Their function is to prevent micro-welding between two metal surfaces during periods of metal-to-metal contact. They do not provide protection by keeping the surfaces separate, as oil does. (Of course, additives might have multiple functions, such as corrosion protection which would help to reduce iron levels.)

EP additives protect surfaces during those periods when the oil film is breached. They do this by reacting with the iron at high temperatures created by friction and oxidizing the surface. This oxide film prevents micro-welding which leads to spalling. The act of protection does cause a micro amount of iron oxide to form which eventually ends up in your oil analysis; whereas chunks of metal from spalling are too large and do not end up in the oil analysis. Thus erroneous conclusions about their effectiveness when only using oil analysis to judge their effectiveness or lack thereof. Who cares if a few ppm of iron is oxidized from the surface in the act of preventing a chunk from being torn from the surface!

Normally, high levels of EP additives are used in gear box oils and hydraulic oils, such as 5606, but not in combustion chamber oils as the act of bore polishing is detrimental to a honed surface (which is not a concern in your engine with channel chrome cylinders).

Improvements to the Slick Magneto



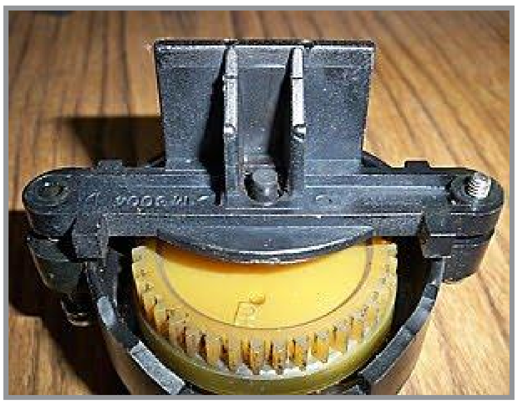
Since Champion purchased the Slick magneto line from GE, they have made some good improvements to the magneto. Expect more in the future!

Here is one example, the new ribbed distributor block (K3822 or K3823). The ribs help capture conductive carbon dust that wears from the brush and provides for a longer dielectrical path that reduces flash-over potential.

A close-up of the K-3822 block showing ribs.

This is the older non-ribbed style:

This is what happens when with the old style distributor block if the carbon dust builds-up to the point that a conductive path exists from the carbon brush across the block.



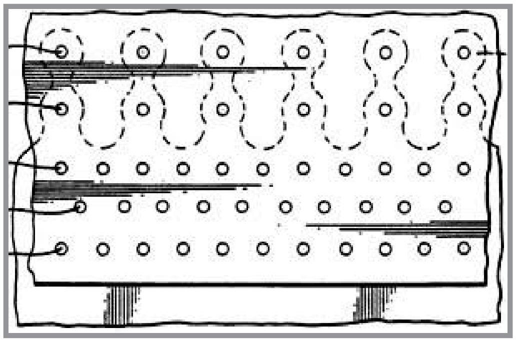
If you repair or overhaul your Slick magneto you might want to replace the block with the newer style one:

K-3822 for 4 cylinder Slick 4300 series magnetos and K-3823 for 6 cylinder Slick 6300 series magnetos. You can purchase these from Sacramento Sky Ranch 800-433-3564 or www.sacskyranch.com

What is a Finger Doubler?

"The finger doubler repair is, in the opinion of the author, the best compromise for a permanent repair to a basic fuselage structure." T.Swift, Repairs to Damage Tolerant Aircraft", FAA-AIR-90-01

A finger doubler is a type of skin lap splice that has a number of advantages:



1. Does not hide cracks. Easier to inspect from the outside. The critical locations for future fatigue cracks are in the basic skin at the first attachment row in the doubler. A finger doubler does not degrade the inspectability of the basic structure because a crack propagating in the skin at this first row will be externally detectable.
2. The purpose of the fingers is to reduce the first fastener peak load stress and thereby increase fatigue life. The fingers at the end of the inner skin are flexible and softens the load transfer through the rivets from one skin to the other at the end of the splice.
3. Reduces skin bending stress by increasing the distance between rivets.
4. Increased distance between rivets permits any crack to grow longer and thereby easier to detect.
5. Avoids the need of drag-producing protruding-head rivets to reduce bearing stress. Allows the use of countersunk rivets because of lower peak load stress.

References: Patent US5297760 *Repairs to Damage Tolerant Aircraft* by T.Swift, FAA-AIR-90-01

Slick magnetos and propeller strikes

Hi John, a couple of us mechanics have been talking about what a Slick mag needs after a prop strike, I've been on the Unison website and can't find any info, where could I look for something in print?

I am not aware of any Slick recommendations for inspection after a propeller strike. Of course, Champion/Slick would be the people to ask.

In my experience of doing propeller strike inspections (approx. 12 per year for 10 years), magnetos were never part of the inspection. This was before Continental/Bendix added their magneto inspection requirement. My recollection (it is often faulty at this age), is that they blamed distributor gear tooth breakage in the magneto on sudden stoppage/propeller strike. Picture below is the distributor gear with broken teeth:

Our opinion is that this breakage is caused by worn bushings creating a conical oscillation about the center axis (whirl or shopping cart wheel flutter). This is a very rare event but we have witnessed it on a magneto test bench.
For more opinions on propeller strikes: Should an engine be torn down after a prop strike?

Fingerprint Corrosion on Aircraft Products

Many years ago our aircraft hose manufacturing shop http://www.sacskyranch.com/ set up a program to identify and eliminate products that might cause chloride contamination. Every chemical introduced into the area is screened for chloride or other potential corrosive materials. This program is not a bad idea for any repair facility working on advanced aircraft products. What we couldn't eliminate was the human touch and the secretions deposited onto surfaces. Fingerprints cause corrosion, and police are using it to identify individuals who have touched brass cartridges years ago:

"We recently showed how fingerprints on brass cartridge cases that we left out for several days in open air at room temperature can still produce corrosion sufficient for visualization, even after they have been washed in warm water and detergent to remove the residue"

Our concern is corrosion pitting that might damage a critical aircraft part. So what can you touch and what should you be careful with? How do you clean fingerprints from parts? read more on my web site...

Inspecting High Strength Materials

The Aardvark Syndrom - built strong but easy to break

Drop a glass onto the floor and it shatters, drop a block of wood onto the floor and it doesn't - yet both have approximately equal tensile strengths. A high tensile strength steel bolt might be twice as strong as a mild steel bolt yet it fractures in two whereas the mild steel bolt bends but still holds the structure together.

We learn to handle glass objects differently than wooden or metal objects because "they break easily"and "are brittle." For the same reason if we use brittle materials in structures we need to 'be careful" and provide additional protection to avoid breakage. A high tensile strength steel bolt might be 3 times stronger than a mild steel bolt but it takes 10 to 100 times less energy to break!1.

A mild steel bolt can handle small nicks, or a little bit of corrosion pitting not because it is strong but because it is hard to fracture (crack). Even if it does crack, the crack growth is so slow that we use various NDT methods to detect cracks and replace the bolt before it

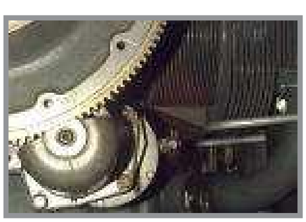
breaks.
Not our high-tensile steel bolt. The energy required to break it is 10 to 100 times less. A bit of corrosion that creates a pit that concentrates stress might be all it takes to start a crack. Because it doesn't take much energy to grow the crack, the part may fracture as fast as a broken glass.
There are various methods of using "high-strength-low fracture energy materials, such as better envirnomental protection, non-critical applications, redundent load paths, crack arresting structures. But using a high tensile steel bolt ("Grade 8") as a single point of attachment on a trailer hitch that is bathed in road salt and submerged in lakes where corrosion occurs hidden under the head or shank is not one of them. A better idea would be to match strength with fracture energy!

More inspections are required for high-strength low fracture energy materials:
- More frequent inspections for corrosion.
- Protection from scratches and marks.
- Protected tooling that won't mar the surface.
- More frequent application of corrosion inhibitors.
- More adequate and detailed inspection and rejection instructions.
- Increased education of mechanics and their employeer on why this is so.

For procurement, better quality audits of the manufacturing process, as these parts require more precise materials , process, and heat-treat.

Note 1. Approximate work of fracture J/(m squared) for mild steel is 100,000 to 1,100,000. For high tensile strength steel it is approximately 10,000.

Starters and Worm Gears in Aircraft Piston Engines



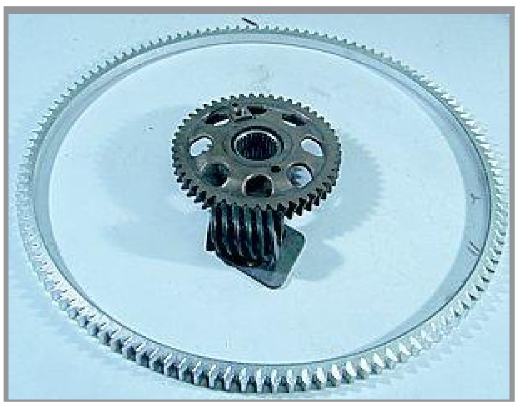
Ever notice how Lycoming and Continental use completely different designs to interface the starter to the engine? We'll focus on the gearing differences between the two.

Continental uses a "starter adapter" for most of their engines that houses a worm gear and clutch mechanism.

Lycoming uses a starter ring gear" mounted to a large "Support Assembly" attached to the crankshaft flange. There are several engineering trade-off's of the two:

- Lycoming keeps gearing out of the engine. If gear teeth break they don't contaminate the inside of the engine.
- The heavy Support Assembly might provide some vibration dampening.
- The starter adapter is compact and light weight.
- The starter adapter can serve multiple purposes by mounting a pully or dampner to it.
- The Continental starter adapter has been an expensive item to repair at overhaul (or in between) so Continental engines have one more expense.
- The Support Assembly is like a large flat plate out in front of the engine that prevents tapering the cowling at the nose.
- You can mount a pully or pully's to the Support Assembly to drive alternators and vacuum pumps.
- The Support Assembly can have electrical contacts in the form of circumferal grooves to transfer electricity to the propeller deice system.
- Both systems have had their own unique problems so it is a trade-off in my opinion as to which one is more reliable. But the Lycoming is less expensive to maintain.

The fast rotating starter needs to be geared down to the proper starting rpm for the engine. This is where the comparison becomes interesting: Lycoming uses a pinion and gear (small gear on the starter is called a pinion) to achieve the proper gear ratio. Continental uses a worm and gear "worm gear" to achieve the proper gear ratio. Lets compare the two:



The Lycoming starter ring gear is on the outside and the Contintal worm and gear is on the inside. Notice how compact the worm gear is? Worm gears are often used when large reductions in gearing are needed. In this example, a fast turning starter motor turns the worm. The engine is then turned by the gear - at a much slower rate. Compare this with the large Lycoming starter ring gear that does the same thing but is 2 feet across.

This is a close-up of the Continental worm and gear. Mounted on the back is the clutch spring and drum that disengages the starter when the engine starts. When it works it works well, but there are lots of parts that have the potential of failing and releasing bits of metal into the engine.

The typical worm gear has a brass gear mounted to a steel worm. There's a lot of rubbing motion across the gear teeth so lubricant needs to be continually applied. The combination of steel on brass prevents cold welding (galling) between the surfaces as lubrication is in the boundry zone where the lubricant isn't always between the surfaces.

Alternator Load Dump by the pilot switching off the alternator circ...

An interesting article by Femi G. Ibitayo of Zeftronics on how the pilot can damage the aircraft charging system by switching the alternator circuit breaker on and off in flight.

A load dump condition caused by the sudden removal of the battery from a rotating alternator may cause these types of damage. In a load dump condition the when the battery goes off-line, the output of a 12V alternator can suddenly increase to 30V or higher, especially when there is no ground on the voltage regulator or alternator controller.

The suddenly or intermittent opening of the battery relay may lead to a load dump condition. The freewheeling diode put across the coil of the battery relates in the aircraft serves as an inductive kickback suppressor or protection device. In this role, it also helps reduce relay contact chatter. Losing this diode may negatively impact the operation and the life of the battery relay. A negative going pulse of a magnitude higher than its forward current rating can damage the diode.

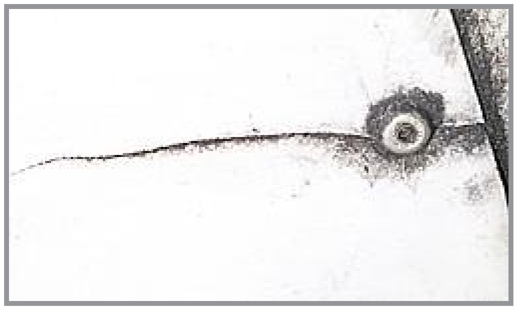
Load dump conditions can happen if the main alternator circuit breaker opens and closes suddenly while the alternator controller is still supplying current to the alternator's field. Sometimes pilots will pull and push back in the alternator's output circuit breaker at cruise speed. This is the point the alternator is capable of supplying very high and destructive voltage and current output. Pulling the breaker under this condition leaves the alternator's stator with all the energy it produced pent up. Pushing in a breaker under this condition connects alternator to the bus and introduces the uncontrolled pent up energy on the system bus as very high voltage and current pulses. These pulses seek the best/easiest current paths and can damage electrical loads in the system. For this reason, we recommend to the pilots and mechanics that we deal with that they avoid pulling any main alternator circuit breaker while the alternator is rotating. The energy experienced in this situation is similar to what happens in a spark plug. To turn off a rotating alternator that has power to its field the best and safest practice is to turn off the alternator field switch first and then if necessary pull the main breaker. read more...

Rivet Edge Distance

Rivet Edge Distance
what happens when you place rivets (or other fasteners) too close to the edge in primary aircraft structures
Rivet tearing (bearing critical failure)

Fatigue crack in aircraft skin from rivet hole
Strength starts to decrease when the distance from the center of the hole to the edge

gets below 2 times the hole diameter (2D)
If your edge margin is below 1.5 then the joint is critical for tear-out of the material or fatigue cracking.
Read more about rivet edge distance...



Some thoughts on camshaft lobes

From previous articles I've written on inspecting camshaft lobes, one point that possibly wasn't stated clearly is that the typical camshaft lobe failure is not a lubricant failure. Signs of lubricant failure show surface sliding damage such as scuffing, scoring, and metal transfer across the surfaces. Not that this doesn't occur, especially, in later stages of lobe disintegration, but often the primary failure that starts the whole process is not related to lubrication.

If you look at the initial damage on a camshaft lobe what you see is a good engineered surface with irregular shaped potholes. A pothole is a good analogy as both a camshaft with a follower rolling on it and a road surface are both non-conforming surfaces with Hertizian type stresses. Potholes in roads release chunks of asphalt with top road surface in good condition. Same with a camshaft lobe, the surface doesn't look bad in the early stages of failure. It's just that small flakes are missing. There is a simple reason for this, the highest stress is below the surface.

Whenever you have rolling or non-flat surfaces, the highest stress occurs below the surface. This is called hertzian stress. Fatigue cracks start off below the surface, enlarge and eventually a chunk of material is released. The wear scar often clearly shows crack

formation and crack growth.
Lubricants are not involved in this process. Not that a lubricant isn't necessary for preventing surface wear, but subsurface fatigue cracks are not affected by lubricants. Failure is determined by the magnitude of the stress and the number of stress cycles. So whenever you add one of those calcium fortified camshaft lubricants to your engine oil, do not expect miracles. Given enough time and hours, all camshaft lobes fail through Hertzian fatigue.

Preflight Inspection Tip - Inspect the muffler

Recently dealt with an old Cessna 180, with 470. Owner has flown 60 hours since buying aircraft 5 months ago. Prior to purchase, the sellers engineer stated that entire left bank cylinders went cold on one occasion only, and after failure to diagnose a reason, it cleared itself after running at 2000 RPM.
The condition reoccured for the buyer, this weekend. This time it was the right bank that went cold, and idle RPM was 1000 RPM. The current owner, during a subsequent run-up attained 2000 RPM, at which point the engine smooted out and all returned to normal. I invstigated today, and found the right muffler flame tube missing. There are obvious signs of very recent failure of the cone. I do feel the exhaust obstruction prevent the entire right bank to breath properly and fire. This same thing likely occured sixty hours ago with the left muffler, but the engineer at that timefailed to identify it. Both mufflers are now just open top to bottom. In reading so many reports etc. on the web it's obvious that this is a little known condition with huge consequences when not inspected and maintained properly. I'd like to suggest that it should have a spot as a possibility in unexplained rough engine operation or loss of power. Below are just a couple of the links that I passed on to this pilot (new customer) regarding his mufflersystem.

Following was copied from Archer Bravo http://www.archerbravo.com/bravotips.php

April 13th, 2006

Don't Get Muffled
When doing your pre-flight walk around, don't forget about your muffler! Here's how to check it: use a flashlight and look all the way up inside the exhaust pipe. You should then see the muffler. If its internal baffling is shaped evenly (cylindrical or conic shaped), with evenly sized holes, it's in good shape.
If it appears warped and distorted, this means the flame cone is fatigued, and it will no longer do its job of vaporizing gas.
Eventually, the parts might begin to shed, and come out of the tailpipe. This can block it, decrease performance, and increase the chance of fire and/or carbon monoxide poisoning. Yes, this is the worst case scenario, but certainly the last thing you want. By the way, some mufflers weren't created with a baffle, so don't panic if you don’t see one initially.
One other important note: if you are in-flight and experience loss of RPM, or rough engine - and your systems check reveals no other problems (magnetos, carb ice, etc), do an inspection of that tailpipe and muffler upon landing.
Submitted by: Flight Instructor Mariellen Couppee
CFI, CFII

info@genehudson.com

Following was copied from http://www.patentstorm.us/patents/5496975/description.html

One type of present day small aircraft muffler currently used has a series of cones that are tack welded to small diameter rods. This assembly is placed within a housing that has an inlet and an outlet. Although this muffler design works well to muffle noise, it has a tendency to fail. Vibration and heat often cause one or more of the cones to break free of the welds. In many cases, the outlet side cone will invert and become lodged in the outlet of the muffler causing immediate power loss due to extreme back pressure in the introduction system. If this power loss occurs during takeoff, a crash is highly likely.

Following was copied from http://www.supremecourt.ohio.gov/rod/docs/pdf/8/2009/2009-ohio-5365.pdf

The engine logbook to the aircraft contains an entry dated August 28, 1987 that states "replaced muffler," which was entered by Edward Ramsey, an FAA licensed airframe and powerplant ("A&P") mechanic. Appellants, through their experts, maintain that the logbook entry establishes that the original muffler was replaced with a new muffler. Appellants' theory of liability is that the aircraft experienced a sudden loss of engine power when the muffler's flame tube separated and blocked the exhaust.

Another excellent reference,

AC 91-59 A,
Inspection and Care of General Aviation Aircraft Exhaust Systems
http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/882287e4ffbbc3ec8625732400584d69/$FILE/AC%2091-59A.pdf
see page 2, 4 b for the following

As an example, we received a safety recommendation concerning the internal failure of a muffler on a Cessna 207 airplane. The cone, which deflects or helps distribute exhaust gasses inside the muffler, came loose and blocked the exhaust gas outlet resulting in engine power loss during takeoff. This mufflerconfiguration is common or similar to many other general aviation airplane mufflers.

Elsewhere in this same AC,

(3) Partial or full engine power loss caused by loose baffles, cones, or diffusers on mufflers and heat exchangers that partially or completely block the exhaust gas outlet flow. This condition may occur intermittently if internal components are loose within the muffler and move around during subsequent flights.

Regards John, as always I continue to push your toolbox as an excellent resource for anyone involved in aircraft.

What's wrong with Aircraft Drain Valves?

Each quick drain becomes another point of failure and another maintenance expense
Fuel drain valves are often a necessary evil as they allow checking and purging fuel tanks of water and sediment. But oil quick drains are not necessary and one should be aware of both the advantages and disadvantages.

Replacing a drain plug with a valve doesn't come without a price. Drain valves require maintenance and a handy supply of spare seals as you never know when they are going to leak. Oil drain valves can stick as sedement and sludge get trapped between the moving parts.
Valves have to be removed, inspected and cleaned periodically. They are not maintenance free! Do you really need an oil quick drain?

When rings should be replaced on aircraft cylinders?

I have a question on when rings should be replaced on aircraft cylinders? When I worked at --------- in Cameron park for ----- --------- he had the policy that any time a cylinder was removed the cylinder was honed and the rings were replaced automatically regardless of time or condition. This seemed like a sound policy. I have seen many instances where cylinders have been removed and the rings were not replaced nor the cylinder honed. Do you have any guidance on this subject?

In my opinion if the cylinders are removed and no work done on them (such as removing *the cylinders to gain access to the lower end) then they need not be honed or re-ringed. Our shop did this many times on propeller strike inspections for example. In this case we would slide the piston out far enough to remove the piston pin. This was done when the conditions warranted: engine was within manufacturers recommended TBO for hours and years; engine compression and oil consumption was normal; no outward signs that something was amiss with the cylinders.*

It is sound policy to replace the rings anytime you hone the cylinder.

How to properly ground a dual magneto?

We have been batteling a recurring issue with a customer of ours, with burnt contact assemblies and capacitors long before they were due to be replaced.Recently we visited the customer, and inspected the installation as part of other issues with that aircraft, to find that the P-lead shielding was peeled off about an inch from the bead nut, and there was no actual grounding between the p-lead and the mag. Now from what we understand, the grounding path in the airframe is from the capacitor to harness housing, through the magneto clamps to the engine, to the engine frame, then to the airframe, but if there are any issues in that chain, the magneto would not ground out properly, like a magneto pressurization gasket, correct?

We would simply like to know what is the best and most efficient way to ground the magnetos to the airframe, and what resources would you suggest.

Scrape away the paint from the harness cap (outside) where the capacitor mounts and this should solve your problem.

D-3000 magneto cap showing capacitor mounting towers

This has solved the same problem others have had. I can't explain why the capacitor isn't adequately grounded to the inside surface of the cap which means I don't fully understand what is happening. Thus I have to rely on past reports of solutions to the same problem.

The magneto need not be grounded to the airframe to complete the circuit - engine will run without any p lead connections - however if the capacitor isn't being grounded through it's mounting then the shielding can provide an alternative grounding path.

I have also seen the capacitors fail from the magneto getting too hot. In this case the rubber capacitor legs were toasted.
There should be plenty of ground (return path) between the magneto and engine through not only the magneto mount clamps but also the shielded ignition leads so there is no reported problems of the engine not firing because of a faulty ground. The capacitor is another story - the magneto will run and fire the plugs without a capacitor even installed so I treat the capacitor as a closed-loop circuit internal to the magneto - or in this case magneto + harness cap. The cap, even if insulated from the magneto by a flange gasket and painted screw holes, should still have a ground path through the shielded ignition leads. But I have to admit it appears otherwise in cases like your's. I think you are on the right track - fix all the grounds, p-lead insulation grounded at both ends, remove the paint from under the capacitor, and possibly make sure the screws holding the cap to the magneto are contacting metal.
D-2000 / D-3000 magneto capacitors Inside view of D3000 hoarness cap

Hose dash size to Inside Diameter

Such a simple title. But this is the world of "dash size" and military standards. Here are the documents that control dash size inside diameters:

Per MIL-F-5509D "Fittings, Flared Tube, Fluid Connections" referes you to the following specifications for internal dimensions:

- MS24385
- MS24386
- MS33649 "Straight Thread Boss"
- MS33656 "Fitting End Flared Tube"
- MS33657 Bulkhead Fittings
- MS33658 Fitting End Hose connection - obsolete, replaced by AS5132 Must purchase from ASTM. Hose end fittings vary depending on hose type and if the fitting has an angle or not and the type of hose.

For External ANPT, such as AN816 flared tube to tapered pipe male consult AND10052. For hose ID see hose specifications MIL-DTL-8794 for 111 hose. Each hose type has a different ID and angle fittings have a different ID than straight fittings for the same hose! Consult MS33658.
A common mistake is to think all hose of the same dash-size has the same inside diameter. This is often noticed when someone is replacing an older style 111 hose with a more modern Teflon-hose. The Teflon hose has a noticeably smaller inside and outside diameter than the 111. The question arises as to why the same hose dash size has different inside diameters. Shouldn't they be the same?

The dash size of a hose does not tell us what the inside diameter is. Different hose types with the same dash size will have different inside diameters.

This is not unique to hose. For example, aircraft fluid carrying tubing is similar in that the size of the tubing is the O.D. not the I.D. So 3/16 inch tube is 3/16 O.D. The inside diameter depends upon the wall thickness.

Even the hose fitting inside diameter is different. Angled fitting usually have a smaller inside diameter than a straight fitting for the same hose. A hose with a straight fitting on one end and an angle fitting on the other end will have different inside diameters.

Industrial and automotive hose is sold by the fractional size. This is the nominal (approximate) inside diameter of the hose. For example, MIL-H-6000 3/8 hose has a nominal inside diameter of 3/8 inch. Aircraft hose is sold by the dash number.

The most full-proof method of determining what size hose assembly you have is to measure the thread diameter on the fitting and compare with the chart below.

Replacing the Spark Plug Helicoil in Lycoming and Continental Engines

520112-3 Helicoil

Lycoming and Continental spark plug helicoils use a serrated teeth to lock the helicoil in place. Spark plugs come in "short reach" and "long reach". Shown here is the short reach plug with a Continental part number helicoil.

Following a Major Defect Report investigation involving two in-flight incidents of blown spark plugs from the same cylinder position on the same aircraft, there is clear evidence a large number of approved workshops are not aware of the correct procedure for replacing spark-plug-helicoil-inserts. Read more...

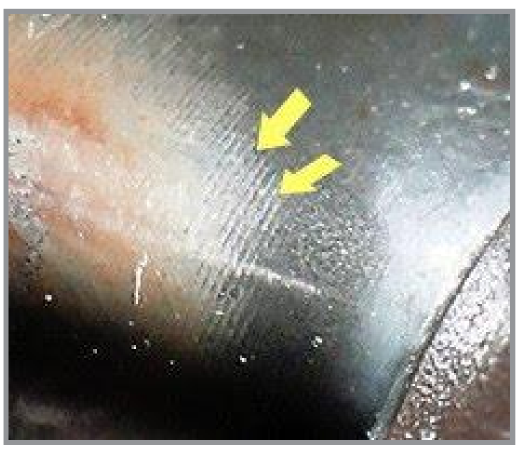
Engine Break In

Engine Break-In is the process where the rubbing action between two hard surfaces forms a flat surface of sufficient area to support the load. The flat surface is called the "bearing area".

Machined surfaces are not perfectly flat but contain microscopic high and low spots. When two surfaces are pressed together, such as a camshaft follower against the camshaft lobe, initial contact occurs only at the high spots. These high spots are crushed, deformed, and worn away until the load is spread across sufficient surface area to support the load (reduction of Rpk or the portion of the peaks that are worn away).

We usually use the term "Break In" to describe piston ring seating but there are many areas where break in occurs. For example:

- piston skirt and cylinder wall
- roller element bearings
- camshaft lobe and camshaft follower
- gear teeth
- rocker arm face and valve tip
- rocker arm socket and push rod ball
- threads, as in threaded fasteners
- sealing surfaces such as flared hose fittings.



What does break-in look like? The picture below shows a slightly worn camshaft lobe. Now look at a close-up of the surface below. Notice the strips at the yellow arrows. These are called "shadow flats" . Metal-to-metal contact has occurred at the light areas and no contact in the dark area. The reason they are lines is that when the cam lobe was ground the grinding wheel leaves microscopic gouges where the abrasive particles ploughed a trough into the surface. The surrounding high spots are not large enough to support the load from the follower and wear down. Can we avoid the break-in process by making parts with better surface finishes? There is a process that attempts to form a compatible surface finish during manufacturing, called "superfinish" but the process is both expensive and often severely abused by marketing huskers. You might conclude that a "superfinish" would be a perfectly smooth"mirror" finish as it provides the largest bearing area. In some areas, such as bearing journals, the smoother the surface, the thinner the lubricant can be before high spots on mating surfaces come into contact. However, it's hard to maintain a lubricant film on a perfectly smooth surface. In some areas, such as a cylinder wall, we require both a flat bearing area and surrounding low areas that provides a reservoir of oil to keep the surface lubricated. This is called a "plateau" finish. The picture below shows a honed finish on a Lycoming aircraft engine cylinder.

This is called a "cross-hatch" finish as the hone motion criss-crosses. The cross-cross pattern keeps the piston rings from spinning as might occur if the hone created a spiral pattern.

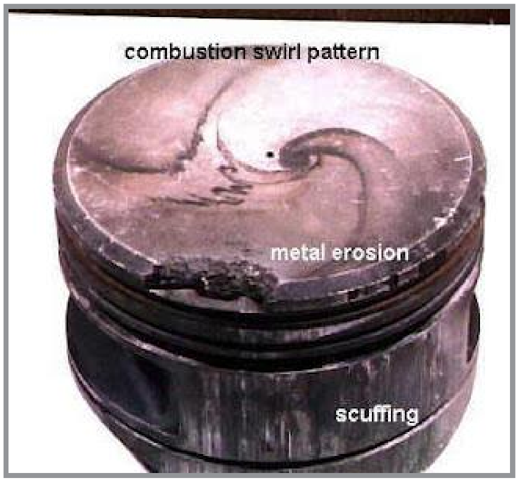
During break-in the high spots are ripped, torn, and abraded down until the surface area is of sufficient size to support the load from the piston rings and the piston skirt. (It's the

piston skirt pressing against the cylinder wall that provides the torque that turns your propeller).
In normal break-in the process stops when the peaks are flattened down to a sufficient area to support the load. The load being the maximum load produced during the engine run-in. This is why the engine should be set to maximum loading (power) during the break-in process. Not immediately, as too violent grinding away produces heat and may start ripping away at the base metal, but gradually bring up the power over an hour or two. The break-in stops when the flat surface, called a "plateau," is sufficiently large to support the pressure from the mating surface. The troughs or valleys left over from the honing remain and are reservoirs that keep the surface wetted with oil.
Enough on cylinder finish. Often neglected are other surfaces such as those listed above. As surfaces get to know each other they are unique onto themselves. Camshaft lobe to lifter, push rod ball to rocker arm socket, each one has formed compatible wear surfaces. If you go mixing them up then the break-in process is repeated to some extent. This is why you always put back camshaft followers back in the same spot as you removed them. You should do this for all wear or contact surfaces: keep pushrods identified to rocker arms so they go back into the same spot, which, by the way, mechanics seldom do but should.
You can read more on cylinder honing and aircraft engines from my book the Sky Ranch Engineering Manual.

Stuck Piston Rings in Lycoming - What to do

Dear John, I have a TIO-540 in an Aero Commander and recently I had a stuck ring. I attached a photo of the piston/case and you can see a lot of buildup. The engines have about 650 since major and I change the oil (Aeroshell W100) every 25 hours. They run relatively cool and I usually run lean of peak at just under 65% power. I attached a recent oil analysis and everything is pretty normal except the dissolved solids are kind of high. We changed the cylinder but I am concerned that it will happen again. I have had no valve sticking issues. Is there anything I can do to remove/reduce the deposits and clean the ring grooves? How do you feel about MMO? How about engine flush concentrates? Any advice that doesn't involve removing all 12 cylinders would be much appreciated!

The dark staining below the ring is not normal and indicates gas past the piston ring belt. The oil control ring (lower ring) has black chunks between the rails. Top two ring faces have black staining indicating ring leakage.
You have combustion gas leaking past the ring belt - i.e. "low compression" due to faulty piston ring/cylinder(s) . Everything else you mention is just a symptom. Hopefully, this is occurring in only this cylinder and will be corrected with the replacement cylinder. If the oil still turns black then the problem has not been corrected.
The problem has nothing to do with your oil type, change frequency, leaning. It is a mechanical problem.



MMO will not fix leaking piston rings. Instead it is an attempt to mask the problem until a more serious failure occurs.

Hi John,

Thank you very much for your advice. I do have very good compressions when doing a diff compression test. I get at least 73/80 and often better. But I think you are right that I am getting blowby past the rings which is turning the oil dark. I burn 1 quart every 4 hours approximately, and the oil consumption is less with higher power settings. Both engines are exactly the same and have the same wear pattern in the oil analysis. If I regularly use MMO do you think I can prolong things until I have the top ends done? What is the likely failure mode besides sticky rings?

The dynamics of ring leakage during engine operation are far different than when the engine is cold and turned off. A compression test does not always detect dynamic ring leakage. It's best to use a compression test as one tool of several to access engine condition; High oil consumption, dark oil color, higher than normal oil temperature, and any abnormal amount of oil out the engine breather, and oily spark plugs should also be considered as signs of piston ring problems.

<u>What can go wrong with continued operation:</u>

I'm not good enough to do predictions. I would access the engine's airworthiness per Lycoming and FAA standards and let the chips fall where they may.

Oil past the piston rings and in the combustion chamber lowers the octane rating (and possibly increases the engine's octane requirement) which can lead to detonation. This was the big issue in the Chevron misfuel debacle in California back in the 1980's? when Chevron had to purchase 1,000'nds of engines. A small amount of jet fuel mixed into the avgas did cause big problems. Below is a photograph of what happens when you mix a bit of oil into avgas. Are you sure engine problem is engine wide? All of that combustion gas makes the whole engine look bad but it can be from one source. I think I would pull the bottom spark plugs and see which ones are oily. The ones that are dry and gray and pass a compression test are probably ok. The oily ones, well the rings are leaking and they need attending too.

I don't believe MMO has any usefulness in the aircraft industry. It does not cure a problem and at best masks it until a small problem becomes a big problem.

Can you use a torque wrench to inspect a bolt for proper torque?

What happens when you tighten a bolt? The bolt is pulled longer, “stretched”, and being springy it wants to return to its original length by pulling the joint together. The joint surfaces push back at the bolt keeping the bolt stretched. The bolt is strained in tension; the joint in compression; and our parts are firmly clamped together. But how did we get the bolt to stretch? We tightened it, not only by stretching along its axis, but by twisting it. We stretched AND twisted the bolt. The stretch is necessary as it keeps our surfaces clamped together, but what is the twisting force doing? It might have gone into loosening our nut slightly the moment we released tension on our wrench; or it might still be locked into the joint in which case all of the wrench force you used to turn the nut may still be there trying to loosen the nut. It all depends on the friction between the nut face and the seating surface (an important lubrication consideration).

What happens if we use a torque wrench to “check the torque” on a bolt? If we torque the nut until we reach the “breakaway torque” we have to apply enough torque to overcome the friction between the nut face and joint surface. Until this happens none of our torque is felt by the bolt. Once the nut face is released torque starts to twist the bolt until it overcomes the friction between the male and female threads. Only now does the nut move relative to the bolt and we detect the “breakaway” torque. Notice that the only thing we are measuring is friction. Everything depends on friction. If the friction is more or less than when the bolt was originally tightened then our “breakaway” torque will be more or less than the torque that the assembler applied to the nut. That is the quandary. Did the assembler improperly torque the nut or did the friction change? We have no way of knowing. “The nuts were loose.” Can we check assembly torque by loosening the nut? Same problem but only worse because if the twisting force is locked into our bolt then it might take only the smallest amount of torque to get the nut moving (our breakaway torque) as the bolt tries to unwind. But what if the nut really is loose? Did the mechanic not tighten the nut properly? We still don't know. Take your pick; all or some of the reasons the nut might be loose from the list:

- embedment relaxation of the faying surfaces
- bolt stretch from metal creep (especially at high temperature)
- nut backed-off due to vibration loosening
- wasn’t tightened properly to begin with
- elastic interactions between multiple bolts in a flange has reduced preload (crosstalk).

Determining the degree of tightness in a joint by using a torque wrench to measure the breakaway torque is not accurate and leads to incorrect conclusions. Beware of inspectors carrying torque wrenches.

" When bolt pretension is arbitrated using torque wrenches after pretensioning, such arbitration is subject to all of the uncertainties of torque-controlled calibrated wrench

installation that are discussed in the Commentary to Section 8.2.2. Additionally, the reliability of after-the-fact torque wrench arbitration is reduced by the absence of many of the controls that are necessary to minimize the variability of the torque-to-pretension relationship, such as:
(1) The use of hardened washers;
(2) Careful attention to lubrication; and,
(3) The uncertainty of the effect of passage of time and exposure in the installed condition." quote from Specification-for-Structural-Joints Using ASTM A325 or A490 Bolts

---Thread locking compound "Locktite" Caution---
Checking the bolt by re-torquing after the thread locking compound has cured only tests the strength of the adhesive and not joint tightness. For example if it takes 21 foot pounds to breakaway Locktite 271 but the joint is tightened to only 15 foot pounds then if you check this joint for "proper torque" by applying 15 foot pounds, the joint can be completely loose and you're torque wrench won't create any nut rotation because the thread adhesive is preventing nut rotation.

There is also the risk, particularly if the thread locking compound has not had sufficient time to reach its full strength, that any subsequent torque check of the bolts may break the adhesive contact, thereby rendering the locking compound ineffective.

aircraft battery explosion

Aircraft Battery Explosion - How to prevent Hydrogen gas explosion. Note the battery is burned from the top down. This is a lead acid battery with vent caps - the kind you add water too. During charging explosive hydrogen gas is vented from the caps into the battery box. The box must be vented and have sufficient air circulation to prevent the build-up of hydrogen.
Also, rapid charging a discharged or "dead" battery generates large amounts of hydrogen gas. "Jump starting" a dead battery and then allowing the aircraft charging system to charge the "dead battery" can dump the full capacity of the aircraft alternator into the battery causing large amounts of hydrogen gas. One does not "jump start" an aircraft battery and then go fly the airplane for many safety reasons. This battery blew the lid off when hydrogen gas was not properly vented. Notice several black caps on top of the battery have blown their tops off exposing the lead vent plug. To summarize:
1. Non-sealed battery's must be vented and have air circulation. 2. Never use the aircraft

charging system to charge a dead aircraft battery.
Note: sealed recumbent gas aircraft battery's vent much much less hydrogen gas as most of it is recombined inside the battery. Both Concord Battery and Gill manufacturer Recumbent gas batteries.

Compass degauss

John,
Just read about your airframe degauser, really interested!I have a CubCrafters light sport cub, so much magnetism that the compass is always pointed N/E. Have you had any dealings with this model aircraft and if so what was the success? Have tried to degause with an old modified TV degauser, helped some but not nearly enough. When checking for hot spots with a hand held compass we find a strong field in the firewall/engine mount area, haven't pulled the mags yet to work on this area.

Bill,
I have no experience with CubCrafters.
1. A compass reacts to any piece of iron so is not suitable for detecting artificial "non-earth" magnetism. The reason for this is that iron is always magnetized with the earth's field. Earth's magnetic lines of force find it easier to travel in iron than in air so the iron sucks in the fields and then sprays them out at any radius in different directions. The only method of solving this problem is to add distance between iron and your compass and use the compensator to correct for any remaining disturbance.
It is important to distinguish the two as you cannot degauss the earth's field. The best method without a suitable meter is to clip two paperclips together so one dangles from the other and come up close to suspected magnetized iron parts and see if the paperclip is attracted to the iron. (if it is then you must use a new paperclip as now your paperclip is magnetized and will stick to anything iron).
The key is to:1. Use a meter to detect artificial fields, and2. Use a degausser at that spot that is stronger than the artificial field, and3. Decay the field in the proper manner.4. Go back and check your work with the meter.
This has proven to be the most successful method over the past 15 years since I developed the system. In cases where it doesn't work I refund the rental fee.

Preventing Stainless Steel Screw Seizing, Galling, and Stripping

Increasing Reliability of your Aircraft's Fluid Delivery System

Each hose assembly adds 6 fluid connections:

1. Between hose and fitting x 2
2. Between hose fitting and attachment fitting x 2
3. Between attachment fitting and component x 2

Each fluid connection becomes a possible point of failure.

- Design your to system minimize fluid connections.
- Avoid the use of adapter fittings where possible.
- Consider trade-off's before purchasing popular upgrades such as fuel flow transmitters, remote oil coolers and filters, external engine breathers, etc.

Factory New Limits and other Nonsense

Pure nonsense! I can give you an example of how one engine manufacturer's cylinder barrel new limit is the same as maximum service limit. What... new limit=service limit!

But there is a story behind this so here goes...

Many years ago one of the engine manufacturer's had a problem with excessive cylinder barrel wear on a high-performance airplane model. There was a meeting of the user group for that airplane and there the factory rep assured all of the owners that they would take care of the problem under warranty. They would boroscope the cylinders and any cylinders that had excessive barrel wear (no cross-hatch left i.e. bore polished) would be removed and re-honed.

Fair enough, but some of the owners were concerned that they were going to get back cylinders that were not to new limits and close to being worn out. The factory rep assured them that "any cylinder not in new limits would be replaced with new". More than fair.

So everyone's happy and the factory rep goes to my shop and says "John, we want you to do all of the cylinder work on this warranty problem." OK, I say, "but if the barrel is already worn out and I hone it, it will be larger. I can't hone it smaller so I know they won't be within factory new limits."

John, the factory rep says, you don't understand. You are going to hone it to factory new at +5 oversize. But Mr. factory rep, you don't have a +5 oversize. We do now!

So here is how this works:

Mininum new is 5.000 inches
Maximum service limit is 5.005

Mininum new for 5 over is 5.005
Maximum service limit for 5 over is 5.010

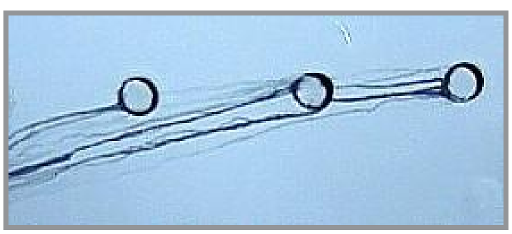
So you see these cylinders were factory new but at +5 oversize, or were they service limit for standard size? Take your pick as they are both!

Now it's not all that bad because maximum service limit is not a wear limit as such. It doesn't mean that the cylinder barrel will stop working at that size. It is a repair limit or the limit of size during repair in which the engine will perform satisfactory during its anticipated life. All things being equal we want it be as close to new size as possible but there is way too much emphasis by users on "new limits".

Now that we're talking "new limits" or 'factory new limits" there is one more gotcha. We got into trouble above by not having a thorough understanding of new limit. Now we're in trouble because of imprecise thinking; marketeers in this industry take advantage of it (you).

If you specify "Lycoming new limt" or "Continental new limit" we can all agree on what this limit is as it is published in their "Table of Limits". But when we say "factory new limits" then who's limits are these? You might incorrectly assume that it is Lycoming or Continental. There are shops that work to their own limits and to them "factory" referes to themselves.

Should Corrosion Preventive Fluids be used on Riveted Joints?



Spraying a corrosion inhibitor into the wings of aircraft results in it's leaking out at seams and rivets and sometimes creating a 'smoking" rivet" appearance. Two possible explanations for the "smoking rivet" are: 1. the lubricant has carried dirt and debris to the outside surface or, 2. the wet skin around the rivet and seam attracts dirt. Some mechanics have suggested a third possibility: that in highly loaded riveted lap joints (such as the Cessna 310 wing outboard of the nacelles), the lubricant might be creating a loose joint. In other words the lubricant is creating the "smoking rivet by interfering with the load transfer of the joint. I have done a literature review to see if this idea has any merit.

Transfer of the applied load through the joint is shared between frictional action at the faying surface and contact between the hole boundary and rivet . Lubricating the faying surfaces might create partial slip and transfer all of the applied load to the rivet. Slip also creates fretting and this leads to cracking. (Farris, T. N., Szolwinski, M. P., and Harish, G., *"Fretting in Aerospace Structures and Materials,"* Fretting Fatigue: Current Technologies and Practices, ASTM STP 1367).

"Comparative flight-simulation tests on four types of joints of 2024-T3 sheet material were carried out with and without application of the penetrant LPS-3. Types of joints were double strap joint with hi-lok bolts, asymmetric strap joint, lap joint with countersunk rivets and lap joint with dimpled holes. Observations on slip during the fatigue tests were made, also in static tests of failure. A reduction of fatigue life was observed in two joints. The effect depends on the design of the joint, while the maximum load in the test may also be significant in view of the occurrence of slip." *Effect of an Anti-Corrosion Penetrant on the Fatigue Life in Flight-Simulation Tests on Various Riveted Joints* Schijve, J | Jacobs, F A | Tromp, P J Natl. Lucht. Ruimtevaartlab. Vol. NLR TR 77103 U, pp. 34. 31 Aug. 1977

"Some aircraft manufacturers and operators have attempted to control in-service corrosion by the use of water-displacing organic inhibitors which can be either brushed or sprayed onto corrosion-susceptible areas of the structure. However, because of the low surface tension and lubricating properties of these preparations, concern has been expressed as to their potential side-effects on the fatigue performance of bolted and riveted joints. Fatigue tests were carried out in repeated tension under both constant-amplitude and multi-load-level sequences on several types of 8-bolt double-lap joint specimens of 2024-T3 alclad aluminium alloys sheet.
Tests were made on joints assembled with either 'dry' components or components coated with the corrosion inhibitors LPS-3 or PX-112. Contrary to the findings of previous investigations into the effect of inhibitors on riveted joints, the two corrosion inhibitors used were found, in general, to have either no effect or a beneficial effect on the fatigue lives of bolted joints. It is concluded that the specific effects of a water-displacing organic corrosion inhibitor on fatigue strength of joints are likely to be dependent on the type of joint, its configuration and on the severity of the load spectrum involved." *Water-displacing organic corrosion inhibitors—their effect on the fatigue characteristics of aluminium alloy bolted joints* A.S Machina and J.Y Mann

"The results showed that the lives of the treated shorter than those of the untreated specimens." *A Short Study of the Effect of a Penetrant Oil on the Fatigue Life of a Riveted Joint* by P. I-f. O'Nei/I and R. I. Smith Structures Dept., R.A.E., Farnborough

"It is concluded that joints fabricated with lubricated rivets, like those fabricated with lubricated threaded fasteners, have lower bearing yield and bearing ultimate joint strengths than when fabricated with clean fasteners." *EFFECT O LUBRICATION ON THE JOINT BEARING STRENGTH OF RIVETED LAP JOINTS* DEPARTMENT OF THE NAVY NAVAL AIR DEVELOPMENT CENTER AIR VEHICLE TECHNOLOGY DEPARTMENT REPORT NO. NADC-72055-VT

" It was found that in joints with high fastener-clamping force, the application of lubricative corrosion-prevention compounds increases the fatigue life, whereas the use of CPC is detrimental to the life of joints with low fastener-clamping force." *Fatigue behaviour of aluminium alloy 7075 bolted joints treated with oily film corrosion compounds*

"The results showed that the presence of CICs had a significant influence on the fatigue life, and also on the failure mode of the joints. At high load levels, the application of CICs caused a reduction in the fatigue life of the joint by more than a factor of two. In this load range, the CICs appeared to cause the failure mode to change from tensile failure of the sheet (the prevalent mode at medium load levels) to shear failure of the rivets (observed at the highest load levels). Specimens that failed by rivet shearing showed some fatigue cracks propagating along the critical rivet row. In treated specimens tested at medium load levels, a reduction in the fatigue life still occurred, with all specimens failing in the sheet. At low load levels, there was little difference in fatigue life for the three conditions, although specimen test run-outs meant that further testing will be needed.

The results are believed to have significance for managing the small aircraft in which these joints are common." *Corrosion treatments and the fatigue of aerospace structural joints* Aditya Jaya Ung Hing Tion , Reza Mohammed, Cees Bil and Graham Clark School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Bundoora, VIC, 3083, Australia

Lycoming Fluctuating Oil Pressure

Below is a description of the problem that is quite lengthy. Sum it up to say that the oil pressure keeps changing. What could it be?

Here is my take on all of this: If you re-label your oil pressure gauge to say "valve opening and closing gauge" then does this better describe what you are seeing on the gauge? Knowing nothing about your engine but having a good seat for the ball seems obvious.

Engine: IO-360A3B6D
Installation: 1980 Mooney 201 (M20J)

Time since overhaul approximately 100 hrs.
Time since overhaul approximately 24 months.
Always in a hangar.

Approximately 6 months ago I started to notice a gradual decrease of oil pressure once in flight. Start-up pressure was good, take-off pressure was good, initial cruise was good, but shortly thereafter it would start to drop.

Where I would see pressure at approximately 72 psi during flight, it gradually became 70, them some time later during a subsequent flight it would 68. That eventually became 66, then 64, then low 60’s and even 58.

By the time it hit the low 60’s I began to adjust the oil pressure relief valve and each time I adjusted it, the initial (start-up) pressure re-established itself at around 90 to 94 with cold oil and in flight I would see 3 or 4 psi more than the previous flight. Generally I would be able to re-establish mid to high 60’s for a flight or two before it would work it way down to the low 60’s. Eventually I ran out of adjustment of the oil pressure relief valve adjustment screw (spring + ball).

One weird characteristic to mention is that the oil pressure would increase on approach to landing despite the lower power setting on let down to landing. If I had 60 psi at the point of flight just before let down with perhaps 23" HG and 2450 RPM, I would see 64 psi at 15" HG and the resulting RPM.

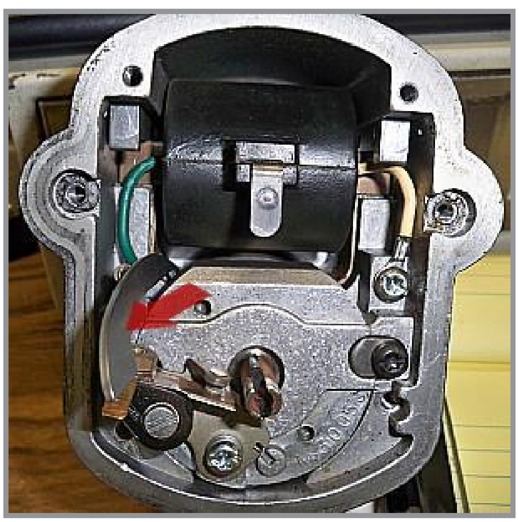
With the spring adjustment now bottoming out, I changed the spring and ball. I installed the next heavier spring then went flying and experienced exactly the same problem. One thing we noticed was that the oil pressure relief seat didn't appear to be round thus not allowing the ball to seat properly. I will be getting the tool to have this corrected. If I read your oil pressure problem check list it mentions that if this problem is experienced then it is likely that the result would be low pressure at low rpm. It is possible that this could affect the pressure at cruise as well or just by virtue of the way the ball naturally moves away from the seat at higher rpm means that this can't be the problem?

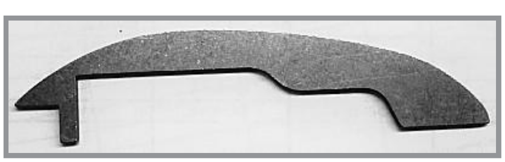
Other items that have been mentioned are the oil cooler (but it was good at the time of the overhaul of the engine, the gauge (I have 2, and a digital E.I. and the ships gauge) and both seem to give the same readings. Both are hooked up to the same oil line. Someone else mentioned the veratherm (spelling?), the oil pressure filter by-pass valve, the oil quantity which I usually keep at 6 because I fing that at 7 it blows it back to 6.

By the way, unless I have a bad oil temp gauge the oil temps are normal (mid-green).

If you have any ideas it would greatly appreciated.

Setting Slick Magneto Point Gap





.008 to .010 inch for Slick 4300/6300 series magnetos. But Wait! You do not set point gap. You set E-gap. On the Slick magneto, E-gap is critical; not point gap - much easier starting! One establishes E-gap (point opening at defined rotor position) and then point gap should be within the limit range.

Shown here is the E-150 E Gap Tool being used to set rotor position. Then use your timing light to detect point opening. By point gap we mean the maximum distance the contact points separate. Reference the Slick Maintenance manual for complete instructions on setting internal magneto timing.
Slick E gap timing tool(red arrow) inserted into slot in rotor and against poll shoes. Notice how magneto is oriented with the coil up. Locate the appropriate L or R timing slot (shown in lower picture) on the rotor magnet and insert the notched end of the T-150 into the L slot for Left-hand rotation magnetos and the R slot for Right-hand rotation magnetos.

Place tool on Left side for L magnetos and Right side for R magnetos. Rotate the magneto clockwise for Left-hand rotation and counterclockwise for Right-hand rotation magnetos until the T-150 rests against the pole laminations. The magneto is now at the E gap position. Adjust the points to be just opening and you have set inernal magneto timing. Point gap opening should be .008 to .012 inches. Torque adusting screw to18-20 in-lbs. Torque the pivot screw to 15-18 in-lbs. Note: many mechanics do not use this simple tool. They estimate E gap. Comparing this method with the tool shown above you can be off considerably. This may account for differences in rpm drop between magnetos when doing the magneto-check.
T-150 Slick E-Gap Timing Tool
Thickness: .060 inch
Length: 2.90

Lycoming camshaft

Got a IO 360 Lycoming L2A in a Cessna 172. Approx 500 hours since last overhaul by a major facility. Cam was not replaced at last o/h and at that time engine had run 2480 hours. They fitted tappet bodies p/no 72877r ohc which I take to be overhauled. We have ferrous metal in main filter, enough to cover your little finger nail. Do you think we are over reacting going for warranty? I haven't pulled a jug yet. There was also a small piece of metal which looks like the tail of a cotter/split pin.

No I do not think you are over-reacting. Something inside the engine stinks and it ain't getting any better.
The principle stress on cam and cam followers is below the surface. Fatigue failure is cumulative and starts below the surface as a crack which eventually reaches the surface and releases a flake. Inspecting and resurfacing "reconditioning" the surface does not restore the fatigue strength. Failure is only a matter of time - total time. Zero time requires that you go back and melt the steel and start over.
Camshaft visual inspection guide

Faulty NTSB Conclusions N9348S

I have to stand up for the mechanic as this NTSB report's "probable cause" is just plain stupid.

NTSB Identification: **CEN09LA209**
Accident occurred Sunday, March 15, 2009 in Bellefontaine, OH
Aircraft: BEECH B24R, registration: N9348S
Injuries: 2 Uninjured. During cruise flight the pilot noticed abnormal engine noises and a partial loss of engine oil pressure. He immediately diverted to the nearest airport, but during the turn to base leg the engine oil pressure dropped to zero pounds per square inch and the engine seized. The airplane was not in a position to reach the runway threshold or to clear the airport perimeter fence. During the landing rollout the airplane impacted the airport perimeter fence, damaging both wings and the nose landing gear.

An engine teardown examination revealed that the Number 3 cylinder connecting rod assembly had separated from its corresponding crankshaft journal. The journal surface was blue in color, consistent with exposure to excessive heat and lack of lubricant. The oil suction screen was obstructed with bearing material. The Number 3 cylinder connecting rod cap was found jammed beneath the counterbalance weight. One of the two connecting rod stretch bolts remained intact. The corresponding nut was found finger tight. The measured torque for the Number 2 cylinder connecting rod bolts were significantly less than the manufacturer's specification. The engine had accumulated a total of 3,799 hours since new and 492.7 hours since its last overhaul in 1999. The engine was last inspected 23.9 hours before the accident occurred.
The National Transportation Safety Board determines the probable cause(s) of this accident as follows:
The inadequate torque of the Number 3 cylinder rod bolts by maintenance personnel, which resulted in a failure of the connecting rod and a total loss of engine power.

" The fallacy here is the idea that measured bolt torque today is the same as what was originally applied some time in the past? The ASTM Specification for Structural Joints sums up the problem: "The uncertainty of the effect of passage of time and exposure in the installed condition." I would add especially after the engine broke into pieces possibly stretching and bending the bolts that remained intact!

When using a torque wrench to break-loose a nut the torque wrench is measuring the amount of torque required to overcome friction.
1. A little bit of off-torque applied to the wrench might be just enough overcome friction and get the nut to turn if the twisting force was locked into the bolt.

2. Friction might have changed due to time or the forces of engine failure on the bolt. The NTSB took a friction measurement that has an unknown relationship to torque applied some time in the past.

3. The two "intact" bolts most certainly suffered from some unusual loading as the engine destructed. If they were yielded and stretched then of course the nuts would be loose.

4. Fretting of the faying surfaces is a classic example of how torque is lost due to surface wear. So the answer is no for 4 reasons.

Torque is a twisting force that tightens the joint not only by stretching the bolt along its axis, but also by twisting it. We stretch AND twist the bolt into a coiled spring. The stretch is necessary as it keeps our surfaces clamped together, but what is the twisting force doing? It might have gone into loosening our nut slightly the moment we released tension on our wrench; or it might still be locked into the joint in which case all of the wrench force you used to turn the nut may still be there trying to loosen the nut. It all depends on the friction between the nut face and the faying surface (an important lubrication consideration).

What happens if we use a torque wrench to “check the torque” on a bolt? If we torque the nut until we reach the “breakaway torque” we have to apply enough torque to overcome the friction between the nut face and joint surface. Until this happens none of our torque is felt by the bolt. Once the nut face is released our applied torque starts to twist the bolt until we apply even more torque until it overcomes the friction between the male and female threads. Only now does the nut move relative to the bolt and we detect the “breakaway” torque. Notice that the only thing we are measuring is friction. Everything depends on friction. If the friction is more or less than when the bolt was originally tightened then our “breakaway” torque will be more or less than the torque that the assembler applied to the nut. That is the quandary. Did the assembler improperly torque the nut or did the friction change? We have no way of knowing.

“The nuts were loose.” Can we check assembly torque by loosening the nut? Same problem but only worse because if the twisting force is locked into our bolt then it might take only the smallest amount of torque to get the nut moving (our breakaway torque) as the bolt tries to unwind.

But what if the nut really is loose? Then take your pick; all or some of the reasons listed below:

1.Embedment relaxation of the faying surfaces
2. Bolt stretch from metal creep (especially at high temperature)
3. Nut backed-off due to vibration loosening
4. Wasn’t tightened properly to begin with
5. Elastic interactions between multiple bolts in a flange has reduced preload (crosstalk).

Checking the degree of tightness in a joint by using a torque wrench to measure the breakaway torque is not accurate and leads to incorrect conclusions. Beware of inspectors carrying torque wrenches.

" When bolt pretension is arbitrated using torque wrenches after pretensioning, such arbitration is subject to all of the uncertainties of torque-controlled calibrated wrench installation that are discussed in the Commentary to Section 8.2.2. Additionally, the reliability of after-the-fact torque wrench arbitration is reduced by the absence of many of the controls that are necessary to minimize the variability of the torque-to-pretension relationship, such as:
(1) The use of hardened washers;
(2) Careful attention to lubrication; and,
(3) The uncertainty of the effect of passage of time and exposure in the installed condition." quote from Specification-for-Structural-Joints Using ASTM A325 or A490 Bolts

Backfiring

Under certain conditions of mixture ratio there will be backfiring in the:

- intake manifold,
- exhaust manifold.

Backfiring in the intake manifold or carburetor: Most frequently occurs during starting of an engine under cold-weather conditions. The priming and choking operation varies the mixture from too lean to too rich. A very lean mixture will burn very slowly and the charge may still be burning when the exhaust valve is closing and the intake valve is about to open. The fresh charge in the intake manifold is not so diluted as when induced in the cylinder and mixed with the clearance gases and consequently will burn more rapidly than the charge in the cylinder. If the fresh charge, upon being induced, is ignited by the residual flame of the previous charge, the flame will travel back through the intake

manifold, burning the charge therein.
Backfiring caused by the slow flame propagation of a lean mixture is not confined to starting, but may occur under any condition of engine operation if the mixture becomes lean enough; it can be made to occur by excessive leaning of the mixture with the mixture control. Backfiring in the carburetor during starting conditions only occurs when the mixture is too lean. Rich mixtures burn faster than lean ones, and under starting conditions the extra fuel which must be supplied to form a rich mixture is probably partially evaporated by the heat of combustion and extinguishes the flame before the next charge is induced.

Backfiring in the exhaust system: Backfiring occurs in the exhaust system under two conditions of operation. The most common occurrence is the somewhat irregular backfiring that occurs when the engine is being motored (driven by the propeller) with the throttle closed. Sometimes you can hear this backfire on airplanes on short final to land. Under this condition the idling system is supplying the mixture. The manifold pressure will not vary much with speed so that the quantity and quality of the mixture in the manifold are practically the same as under normal idling speed. Also, the exhaust product in the clearance space remain the same with speed., consequently as the engine speed is increased due to motoring the amount of the charge per stroke becomes smaller and the dilution greater until firing ceases. The succeeding unburned charges are pushed out into the exhaust system, the dilution in the clearance space is decreased and after a few cycles with no firing, a charge will be fired. It will be a lean and slow burning charge and the opening of the exhaust valve and result in an explosion. This type of backfiring can be eliminated by increasing the richness of the idling mixture.

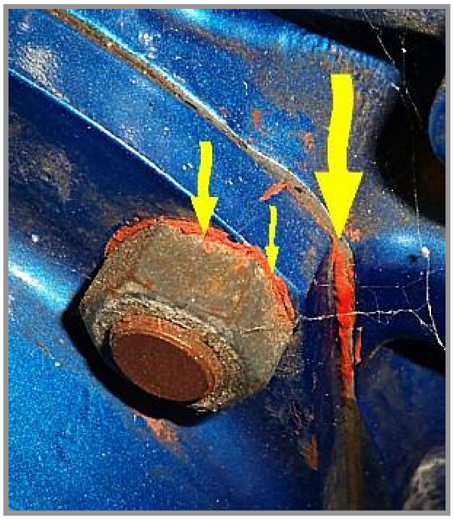
The other condition that results in backfiring in the exhaust system is usually that of a faulty fuel control. Under part throttle operation, a faulty carburetor may cause an enrichment of the mixture which would cause misfiring. Opening the throttle would reduce the richness, and the firing of the charge would be resumed. In the meantime, the unburned mixtures which have collected in the exhaust system have become combustible probably due to the condensing of some of the heavier ends of gasoline, and these are ignited from the flame of a cylinder which fires resulting in a rather violent explosion.

Lycoming Valve sticking Tip

Valve stuck in open position - check for too little valve tappet clearance
If you have a sticking valve along with everything else you need to do to fix the damage and correct the problem, don't forget to check dry tappet clearance. Too little clearance can lead valve's sticking in the open position. Here is a link to how to check dry tappet clearance on a Lycoming engine.

Breaking Studs

"How often have you heard of a broken cylinder hold-down stud? A crankcase thru-bolt? All such failures are closely related and add up to be one of the most frequent types of structural failure experienced in piston aircraft engine's today?" (written in 1953 and still true today!) So let us consider the principal factors producing this type of failure and the



important role maintenance plays in its prevention.

Cylinder hold-down studs, crankcase thru-bolts, and connecting rod bolts are a few examples of critically stressed parts subject to alternating loads. The manufacturer always gives them a specific nut torque range which must be maintained to prevent failure. The minimum torque value is necessary to avoid fatigue failure and the maximum to avoid exceeding the tensile strength of the stud. The vast majority of these failures experienced during engine operation result from fatigue. The nut is too loose, not too tight. When a nut is tightened too much often the nut yields or the stud pulls.

To give a better understanding of stud and bolt fatigue failure, we wish to review some typical applications via a simple illustration. Take a rubber band and note that it stretches in direct proportion to the amount of pull up to its useful (elastic) limit. Any change in stretch shows a corresponding change in load; a constant amount of stretch shows a constant load. Now, wrap this band tightly around two pencils. Assume that they are being held together with a force of two pounds. If you try to separate them with a force of one pound, what happens? Nothing that one can see - the pencils don't separate; the rubber doesn't stretch. And the rubber doesn't "feel" the pull. Why? The rubber band was pre-loaded to a greater force than you applied. The one pound pull only reduced the pressure between the pencils (from two pounds to one pound) and the rubber doesn't know the difference. It will not stretch further until the pull is greater than two pounds. If the band is made of metal instead of rubber and a load exceeding two pounds is applied intermittently, it will fail eventually from fatigue. To prevent fatigue failure, the preload must be equal to or greater than the alternating load imposed.

This principle applies to the cylinder hold-down stud and the other examples mentioned above. Consider the crankcase cylinder pad as one pencil, a portion of the cylinder base flange as the other, and the stud as the band. The flange gets a terrific tug at every combustion chamber explosion but the stud should not feel it - the design pre-load is greater than the pull of the flange. If the stud does feel it, the actual pre-load is lower than the design pre-load. Therein lies the story - "Another broken stud." The solution to this problem sounds simple. Just apply and maintain proper pre-load. But in actual practice a few complications arise. First, the torque method, which is far from fool-proof, is used to obtain a pre-load on the stud. But will all the cylinder hold-down studs get the same pull if each is tightened the same amount? Only if all conditions that resist the nut from turning are equal - thread lubrication, condition of the threads, condition of the mating surfaces, etc. It is important that they be kept as uniform as possible by giving close attention to the physical condition of the mating parts and abiding by the pertinent engine manufacturer's recommended procedures. The torque method has its drawbacks, but it is much better than guesswork and the best method generally available in the field.

The pre-load must remain unchanged. But, if the mating surfaces are not sufficiently hard (as in the picture above) and smooth, they can become indented during engine operation from the pressure exerted by the pull of the stretched stud or bolt. We have discussed how a stud or bolt stretches in direct proportion to the pre-load applied. The stretch also will vary in direct proportion to the effective length of the loaded part. For a cylinder base stud, which is relatively short, the actual amount of stretch is very little - somewhere in the neighborhood of .002 inch. What happens if its nut sinks .001 inch into the cylinder flange during engine operation? The pre-load is cut in half. The stud receives an alternating load many times a second. There is one chance of survival- a continued collapse of the mating surface more than another .001 inch. Then the nut will be finger-loose due to the slight clearance between the nut and the flange (except for intermittent contact permitted by bending of the flange), and the troublesome alternating load will vanish. Of course, other studs now will be overloaded and the cylinder base flange's load will be lopsided. The agony may be prolonged but eventually something is going to give. One of the biggest culprits affecting cylinder base stud breakage is the practice of using goop and sealants under the nut or flange.

This discussion has dealt with the man with the wrench. The integrity of an engine is very dependent on the man who puts it together.

This article is from "Engine Conditioning Summaries" produced at McClellan AFT in the 1950's. The problem of improperly torquing cylinder base studs has not changed in 60 years.

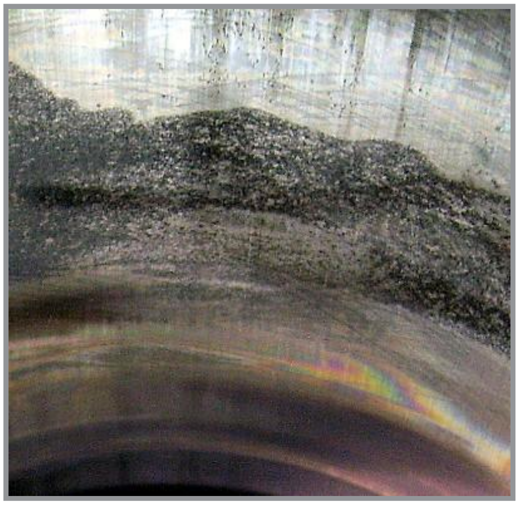
Lycoming cylinder barrel wear signs

Here's some not uncommon cylinder barrels.

First notice I've placed a white piece of paper to reflect the light onto the barrel. Now you aren't looking down a dark hole.

In the next picture the yellow arrow points to a dark patch. Dark patches are almost always areas of corrosion pitting. Next look at the red arrow. Notice two things; the rainbow colors and the shinny appearance. The rainbow colors is a heat tint that forms at approximately 500 degrees F. You should not see any hint tinting in a Lycoming or Continental cylinder barrel. The heat tint tells us the barrel at this spot got too hot. Notice that the heat is local. The heat is caused by blow-by of combustion gas past the piston rings.

Here is a closeup of the dark patch clearly showing corrosion pitting and the heat tint below.
Corrosion pitting is a difficult call. If it is concentrated in one spot it will trap oil that will oxidize and glaze over creating a tan



colored patch on the barrel that will hinder the proper operation of the piston rings. If the pitting is more general then usually it does not adversely effect the operation of the piston rings.
When you look at a pit you might have the impression that "it doesn't look too bad" or that it is "real small" but you are only looking at the entrance to a hole. Pits penetrate deeply beneath the surface and they weaken the barrel. Proceed with caution and consult the manufacturer for rejection standards when it comes to any corrosion on a structural surface. Remember a cylinder is a pulsating pressure vessel. All the torque that turns that propeller is due to the piston pressing against the cylinder wall for leverage. On the other hand if you start rejecting cylinders with pits you will probably ground half our entire fleet of aircraft.

Are Aeroquip fittings usable on Stratoflex hose, and vice versa, ar...

It depends. From a functional or a legal view?
It has been common and accepted practice to intermix Aeroquip 303 and Stratoflex 111 hose and fittings. The reason is that both are made to the same military specification (MIL-DTL-8794 for the hose) and are considered identical. I believe both Stratoflex and Aeroquip "discourage" the practice as neither one has control over the performance of the final product.
Aeroquip 601/701 and Stratoflex 156 (lightweight outside steel braid hose) the same argument could be said however the practice is not as common (ingrained) into the industry.
Teflon hose products: Not done.
Note that I fall back on "common and accepted practice" as the only justification. I cannot point to any authoritative document but just past practice in the industry. This is a thin leg to hand on as all it takes is one FAA inspector to wave his magic wand and disallow the practice. Often "accepted" practices become "unacceptable" as soon as a problem arises. Personally, I have no issues with intermixing hose and fittings on 303 or 111 style hose. I am more cautious with the other hose types.

Is it best to mate them to their own product line up?

Yes it is best to mate them to their own product line as that is how they are performance tested. For example, I know that when I build a Stratoflex 124-4 hose that its ultimate minimum burst strength is 12,000 psi. I know this by testing the product at random intervals not to exceed 500 hoses. If I deviate and build the product using some other method or use other fittings I do not know if it meets specification because there is no testing data that has been done.
There is another reason - As a mechanic one wants to shift as much potential liability

"blame" as one can. Mixing manufacturer's gives each manufacturer an escape clause to deny responsibility if anything goes wrong. Do it per the manufacturer instructions and then if anything goes wrong it must be their fault.

Spark plug anti-seize

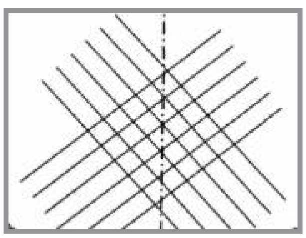
*John: From your past publications: "Champion recommends using 2602 spark plug anti-seize. Use sparingly. Some also use C5-a copper anti-seize although we prefer the Champion product which is a water based graphite."Champion Spark Plug Anti-Seize and AutoLite Anti-Seize contain graphite. I suspect that Lycoming suggests not to use a graphite-bearing compound is because graphite can weaken aluminum.Lycoming quotes the following in their "Lycoming Flyer" (*http://www.lycoming.textron.com/support/tips-advice/key-reprints/pdfs/Key%20Maintenance.pdf*) that "It is helpful to use anti-seize or plain engine oil for spark plug threads starting two full threads from the electrode, but DO NOT USE a graphite-based compound".What is the proper anti-seize to use on spark plugs?*

In aircraft the proper product to use is contained in the maintenance manual so there is no debate. In the case of Champion spark plugs it is 2602. This is also what every large maintenance shop I have ever been in uses so I don't understand why this would be questioned.
C5a is not only not a product listed in any of the manuals that I am familiar with but it is a bad idea for two reasons:1. Spark plug antiseize does not contain any metallic particles that can enter the combustion chamber and cause preignition. (way back when they used to use a mica antiseize which is a mineral that prevents seizing and is also non-metallic so is preignition safe). Small copper particles are not something that one wants in an air cooled combustion chamber.2. Spark plug torque specifications are based on using the proper lubricant (2612 for Champion) and any change in lubricant will change the friction and the torque/tension relationship. Proper torque for C5a is unknown.
The Lycoming flyer recommendation was most likely written by Joe Diblin ("engine joe") some 30 years ago so is somewhat dated. Although I agree with Joe. Graphite and water is an awful spark plug antiseize. I debated about bringing back the BG mica antiseize and selling it as it is a much better spark plug antiseize but the torque issue prevents me from doing so.)

Aircraft Vacuum Pump Troubleshooting

Inside view of a dry vacuum pump. The rotor and vanes are made from carbon. Notice that the top surface of the rotor is shiny or wet looking. This pump broke apart because oil got inside the pump. The oil mixes with carbon dust to form a sticky paste that will seize the rotor causing it to fracture.

Glazed cylinder and high oil consumption



Morning John,
I am finishing an annual on a 1949 Stinson with a Franklin Engine. I was checking your website for photos of a glazed cylinder.I suspect after 50 hours break-in that three of the cylinders did not seat.(excess oil burn, three bottom plugs very oily, oil blowing out of breather.
I plan to do a borescope after the differential press check and then a crank case pressure check.
If they did not break in do you suggest any chemical to pour into the cylinder to break the glaze and try again?

Well maybe not so good morning - about your cylinder...
The only solution is to remove the cylinders and re-establish a proper ring finish. And I emphasis proper ring finish. By proper I mean the ability of the hone shop to measure RMS finish and cross hatch pattern. Otherwise it is a random process with random results.

I don't have any pictures of "glazed" cylinders and I doubt they would look very much different from a normal cylinder. Usually, the term 'glazed" is used rather indiscriminately to describe any cylinder where the oil consumption is above normal after the break-in period. It is usually presumed that the reason for high oil consumption and poor compression is because the rings did not seat, but there can be other reasons such as improper rings or cylinder bore distortion. Failure of a cylinder to form compatible wear surfaces "break-in" is typically caused by an improper surface finish. High viscosity oils and poor temperature control are other reasons why rings do not seat.
There is nothing you can pour into the cylinder to dissolve carbon - but carbon is a symptom and not the problem.

The picture below shows what a hone pattern should look line.
Hone Cross-Hatch Finish Geometry

ROTEC radio noise

John,I found your website and the MF3-A looks like what may do the trick on my experimental aircraft that utilizes a handheld ICOM A-21 aircraft radio. The magneto on the Radial engine is putting out an RF signal that interfers with the radio. It goes away when I ground the mag and operate off the electronic ignition (which replaces the 2nd mag). ROTEC people have no specific recomendations but I think you have the right product to solve this problem. Am I correct in my assumption? Is this the correct suppressor? The ROTEC uses a non descript magneto and is not a Bendix or Slick . I would like to order one if you think it will help.
The MF3-A is designed for certain Bendix magnetos - it may not work or it might make the magneto not work correctly in other applications. How about the rest of your ignition system? Are the leads and plugs shielded?
The all important ignition system utilises two auto type spark plugs per cylinder independently fired by both a single self-energized magneto and Hall-effect 12 volt electronic ignition system, virtually eliminating total ignition failure when used in tandem. Timing is fixed at 22 degrees BTDC.

Shield the P lead wire. That is your first project.

Sounds like it is working as designed unless it is unique to your airplane. Possibly Rotec does not anticipate the use of radios in aircraft? I would push on them until I got to engineering to find out if this is a design feature or a defect.

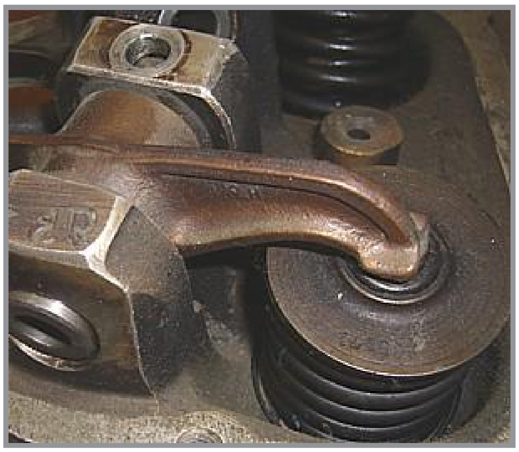
There is a reason why modern aircraft engine use metal jacked shielding on their ignition wires and large shielded spark plugs as long-range radio communication under all conditions is vital to air safety. The aircraft industry moved away from the Rotec design and "automotive' spark plugs in the 1940's. Unless the laws of physics have changed since then, the Rotec design is inexpensive but unfortunately rather old and obsolete.

Don't Forget to Inspect the Rocker Arm

Pitted Continental Rocker Arm Face
When you purchase replacement cylinders the rocker arms are not included. Often they are placed aside until the new cylinders arrive and then installed. The rocker arm pictured above may wear out the valve guide very quickly. We have seen instances of 50-100 hours until the guide is worn sufficiently to cause valve leakage! If you then send out the cylinder for repair and then place the rocker arm back onto the cylinder you will repeat

the problem. Here is what the rocker arm is telling you:
Notice the pitting on the top edge of the rocker face in this picture? The rocker arm face is tilted in reference to the top of the valve stem. The face should lie flat if everything is in alignment. By "everything" I mean the following:

- Rocker shaft boss
- Rocker arm bushing
- Rocker face
- Valve guide boss
- Valve guide
- Valve seat boss
- Valve seat face



Quite a list isn't it. If any one of these are mis-aligned then the face doesn't sit flat onto the top of the valve stem. Here's the quick tip -- After installing the rocker arm carefully look at how the rocker face is sitting on the valve tip. If it is resting flat then you know that all the items on the list above are in alignment. This is a quick, easy, inexpensive, and informative inspection -- the kind I like!

Rocker arm should be flat against valve tip.

What if it isn't flat? Then you have a problem; The valve guides will wear prematurely and the problem can be any of the above. The first thing to check is to see if the rocker face has been re-ground, "refaced". Refacing is an awful thing to do as it is often done by hand, and it ruins the geometry of the face. Even if alignment is retained the cycloid curve is often flattened and this causes the pressure on the valve tip to move off-center causing the rocker arm to push the valve stem into the guide. You can swap a suspect rocker arm with one that is resting flat from another cylinder to check if the problem is the rocker arm or the cylinder. If the rocker arm is bad, replace it. Another tip is to inspect the rocker arm socket for wear. This must form an oil seal with the push rod ball. It is good practice to make sure each push rod goes back into the same rocker arm. The wear surfaces know one another and are compatible. If you mix them up then the surfaces are strangers and must "wear in" and form compatible surfaces.
Inspect rocker arm socket and push rod ball

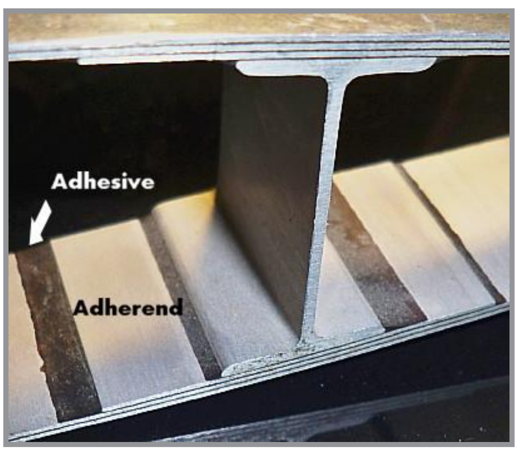
Replacing Spot Welds with Rivets

I am a Mechanic's Toolbox subscriber. I looked through it, but could not find any reference for replacing spot welds with regular 426/470 rivets. The area of concern is in non-structural applications, such as access doors and fairings.I have also looked all over the internet and have even talked with a few structures people and found nothing concrete. The closest is one fellow who verbally stated that it is generally acceptable to replace a fastener with one that is stronger, such as replacing an AN bolt with an NAS bolt.Do you have any suggestions or information?

Your question has been already asked and somewhat answered on this engineering forum. No direct answer but some concerns. See the following link:
http://www.eng-tips.com/viewthread.cfm?qid=42081&page=62

In regards to higher strength fastener replacement - I see more hole failures than fastener failures ("smoking rivet") so concentrate on the condition of the hole. This seems also to be a theme of the link above.

Field Inspecting Bonded Joints - Problems and Expectations



This is the condensed version of an article entitled "ASSESSING ADHESIVE BOND FAILURES: MIXED-MODE BOND FAILURES EXPLAINED"
Field inspections of adhesive bonded joints cannot detect degregation of bond strength. Yet at the end of a "successful" inspection, the aircraft mechanic is to declare the aircraft safe to fly. Is this an impossible task?
Adhesives depend on chemical bonds formed at the interface between the adhesive and adherend at the time the adhesive is cured. If chemical bonds are strong, failure occurs through the adhesive; bond strength is high. If the chemical bonds are weak or degraded, failure occurs through or near the interface; bond strength is low.
For metals, hydration of the surface oxides by water is the most common cause of failure. For example, aluminum forms an oxide almost instantaneously when the pure metal is exposed to the atmosphere after etching or abrasion during the production process. A bond which is susceptible to hydration at the interface has short term strength that may be sufficient to pass certification and quality assurance tests. However, as time in service progresses and the interface gradually deteriorates; bond strength degrades and eventually fails even without any loads.
Many current tests for process validation are based on static strength. For bonds which are susceptible to hydration, the chemical bonds at the interface are initially strong. It is not until the interface has begun to hydrate that there is a measurable loss of bond

strength. Hence, short term strength or fatigue tests cannot prevent the in-service bond degradation and adhesion failures.

Many structures pass certification testing and quality assurance tests, including NDI, therefore one could infer that these are sound structures. Yet these structures may be susceptible to hydration of the interface and subsequent failure in service.

In later service, there is a potential for the adhesive bonds to dissociate so that the oxides can hydrate. This creates an interfacial failure of the adhesive bond. Moisture absorbed by the adhesive is sufficient to start hydration, and paints and sealants are not an adequate measure to prevent hydration because they simply slow down, not prevent, moisture absorption.

Out in the field, NDI can only tell whether or not the bond has a physical defect, it can NOT determine the strength of the bond. NDI can therefore not detect the onset of bond strength reduction. Aircraft mechanics cannot assure the strength of bonded joints and it is up to the regulatory authorities and the manufacturer to recognize the limitations inherent in the inspection of bonded joints.

Aircraft Hose Temperature Limitation Warning

Firesleeve DOES NOT increase the temperature rating of the hose. Its sole purpose is to prevent flame penetration for a short period.

Aircraft Fuel Hose with Firesleeve Jacket Above This fuel primer hose was completely burnt. When the pilot primed the engine he squirted fuel into the firesleeve.

This rubber hose is rated for 250 degrees F (121 C) and was located 4 inches from the exhaust stack. Firesleeve DOES NOT increase the temperature rating. There were plenty of burnt deterioration on the firesleeve to alert the pilot during preflight or the mechanic that there was a temperature problem.

Inspecting Aircraft Control Cable

Is this aircraft cable cable wear acceptable?

Aileron control cable failure on a Boeing-737-3TO on takeoff at Seattle, September 27, 1997 just six weeks after the cable was inspected for wear. Must have been a failed inspection -- yes? Not so quick, the inspection was performed "by the book." The inspection technique and process was at fault, not the mechanics.

The inspection consisted of checking for visible wear (external wire wear). However, the NTSB found that the internal wires were 90% worn! Most notably was the loss of aileron control on another Boeing 737-100, Flight-1659. The NTSB found that existing inspection methods could not detect the breakage of 98 of the 133 strands in the cable! Did you detect the broken strands in the picture above? Here is another picture with the tension removed.

Same cable with tension released

The NTSB investigation found that using professional FAA approved maintenance inspection at the most professional level will not detect dangerous control cable conditions. The broken-strands were not detected using the prescribed method of drawing a cloth rag over the cable. Only until tension was released from the cable were the broken strands detectable. Thus the need to release cable tension to better detect broken strands.

What about measuring the external diameter? The other Boeing standard at the time was to replace a cable when the the diameter of any single wire was reduced by 40%. This is called an "external wear" inspection. However, what the NTSB found in Flight-1659 was that cables wear internally as the individual wires slide past one another. This internal wear is greater on stainless steel cables than on galvanized cables because the galvanizing acts as a lubricant and stainless steel is noted for galling. Therefore, **a maximum allowable reduction in cable diameter specification needs to be specified in the maintenance manual.**

Notice also that stainless steel "the galling steel" wears faster than galvanized steel. Hmm, maybe stainless isn't so good after all.

In the 737-3TO incident illustrates the need for a cable diameter specification. the "NTSB found that several locations where the overall diameter of the **cable had been reduced without damage to the exterior cable surface**, which the NTSB metallurgist characterized as indicative of internal-cable-wear. In some locations, the cable diameter was reduced by as much as 0.03 inches (corresponding to approximately a 30% reduction in cable cross-sectional area for a nominal 3/16 inch diameter cable.)"

Same cable tension released and bent

And then there is the Twin-Otter crash killing 14 passengers in Tahiti in August of 2007 from frayed stainless steel control cables. The poor wear resistance of stainless steel rope has resulted in death and destruction. More frequent inspections are required for stainless steel flight control cables. For more information on this subject reference: Special-Airworthiness-Information-Bulletin:-SAIB CE-01-30, July 11, 2001.

There certainly has been enough time for the airframe manufacturers to update their maintenance inspection processes for flight control cables to reflect the lessons learned by the NTSB.

Engine Balance and the Arms Race

Interesting question about the engine balance "arms race" I've shortened and edited it a little:

So here's my question. Is there any computation or formula that you know of to convert the CH IPS velocity units into the moment units of fixed balancing machines, something that factors in the approximate weight of the whole engine and/or prop?
Here's what prompts the question. Some engine shops now balance engine crankshaft assemblies, and it's sometimes sort of an advertising arms race to split hairs more finely by advertising or claiming the lowest unbalance limit (expressed in moments). Sooner or later, some owner will ask, "OK, your crank balance limits are in different units from the units in the prop balancing book I read. How do your levels of engine balancing precision compare to what is acceptable or recommended for the prop?"

This is not in my area and I don't know a thing about standard practices in the balancing industry, but I can't resist: Reducing the problem to its most basic level:

What Roger calls Arm is the eccentricity of the mass or the distance between the center of gravity and the center of rotation. So in terms of unbalance it is simply the amount of mass eccentricity times the radius (mR).
How do we detect this? We can spin the object and measure the vibration force because when mR >0 the centrifugal forces are greater than zero. We can measure ips, acceleration, g., or pilot comfort or whatever vibration measurement we wish to take. BUT these are all reactions to mR being greater than zero. We have measured the effects of imbalance and not the amount of imbalance itself.
Now Rogers question is astute. He wants to do just the opposite: Having measured the vibration in ips, g's, or human comfort level he is asking for a formula to convert any of these back to mR. I could be wrong but I don't think this is possible without knowing the mass. For example, If you tell me you are experiencing a 1 g force I cannot compute your mass (weight in this case). If Roger knows the mass of the crankshaft (and possibly the rpm, then I believe he could). He could empirically by making changes to the mass.
So if we talk about the amount of imbalance or mass eccentricity and not the vibration caused by the mass eccentricity we can express this in terms of eccentric mass and radius. So if Roger tells his customers that he balances crankshaft's down to "twenty milligrams per millimeter" (1 grain of rice 1 mm from the center of rotation) he will completely confuse the customer and possibly bullshit his way to leader of the arms race. The IPS guy has no idea what the amount of imbalance is - he just knows the amount of reaction there is to the imbalance.
To add further confusion, everyone is assuming that the crankshaft is perfectly rigid which it is not; that is why longer crankshafts have "counterweights" better described as "tuned pendulum absorbers". The crankshaft locally is not balanced as the cheeks are not opposite so we get local reactions to that imbalance. A 4 cylinder Lycoming or Continental engine has unbalanced reciprocating forces that are greater than any rotating

imbalance. So ultimately it's a marketing question involving human nature and gullibility and thus so should the answer be framed.
1 gram is approximately the weight of 1 drop of oil so as the crankshaft rotates it is covered in oil so at the gram or sub-gram level the eccentric mass is always changing and thus crankshaft "balance" under operating conditions is dynamic and no amount of fixed mass will compensate. But for marketing reasons we could assume that some oil pools in recesses or is always present in oil galleys. Why not spin balance the crankshaft with the oil galleys filled with oil or the crankshaft wet to determine its mass eccentricity in real-life conditions and balance accordingly. You could advertise a 'wet balanced" crankshaft.!
Any counter-weighted crankshaft will have eccentric mass at the pins (bifilar mounted counterweights) as different diameter pins are used to tune the counterweight. Possibly one could compensate for this and call it a "bifilar tuned wet balance". Wait there's more we can do: any crankshaft collects a patina, sludge, and carbon deposits that certainly weigh in excess of our grain of rice. Why not advertise a "carbon compensated bifilar tuned wet balance."

Enough of this nonsense -

Bulkhead Hole Size

Dash Size	Thread Size	Hole Size	AN960 Washer
-2	5/16	.328	-516
-3	3/8	.390	-616
-4	7/16	.453	-716
-5	1/2	.515	-816
-6	9/16	.578	-916
-8	3/4	.765	-1216
-10	7/8	.890	-1416
-12	1-1/16	1.015	-1616
-16	1-5/16	1.140	-1816

AN837 Bulkhead Fitting Bulkhead Hole Size Chart for AN Fittings
Here is how bulkhead-hole-size is determined. Use the thread size as the outside diameter of the fitting. For example, a -4 bulkhead fitting has a 7/16-20 screw thread. The hole needs to be slightly bigger than 7/16 inch. A AN960 washer designed for a 7/16 thread has an internal hole size of .453 inch. So we make the bulkhead hole size the same size as the washer internal hole size.
MS21344 is used as a guide for installing bulkhead-fittings. The instructions to the left are from TO 00-25-223 INTEGRATED PRESSURE SYSTEMS AND COMPONENTS (PORTABLE AND INSTALLED). Slight differences between the two documents, specifically in the type of washer used. MS21344 indicates AN960 washer while TO 00-25-223 shows AN901 washer.
The discussion below concerns using bulkhead fittings in hydraulic systems. Note that this is not a good practice and generally prohibited by the military. "Universal fittings conforming with MS33515 and MS33657 shall not be used in boss applications in hydraulic systems..." MIL-H-5440G. Nevertheless, it is used and the bulletin below details problems with this practice.
Special-Airworthiness-Information-Bulletin-SAIB CE07-46 The FAA received reports of leaking hydraulic fluid due to improper installation of bulkhead universal fittings when installed in a hydraulic pump pressure port. The bulkhead universal fittings were turned in too far or not far enough causing the o-ring to contact the fitting threads resulting in o-ring

damage and failure. While superseding standards and specifications exist, this SAIB refers to the installation of standard parts that resulted in the reports of leaking hydraulic fluid. The standard design installation of a bulkhead universal fitting into a port includes specific procedures to assure that the fitting is positioned so that the o-ring is located between, rather than on either of the two threaded portions of the universal fitting. These installation procedures are applicable, unless superseded by the Instructions for Continued Airworthiness for a specific airplane.

Standard designs for installation of a bulkhead-universal-fitting (flared, flareless, and straight threaded connectors) into a port utilize an AN6289 nut with a recess for a back up retainer for the o-ring. The use of an AN924 nut should no longer be proposed as a standard design for a new or modified installation of a bulkhead universal fitting into a port. The use of an AN924 nut instead of an AN6289 nut with a backup ring was initially included within the standard design per AND10064 (for flared tube and straight threaded connectors) for fuel and engine oil applications only. The use of an AN924 nut on a bulkhead universal fitting installed in a port became inactive for design in 1955 via AND10064. Refer to the attached excerpt from AND10064. The use of an AN924 nut instead of an AN6289 nut with a backup ring was initially included within the standard design per MS33566 (for flareless tube and straight threaded connectors) with nominal use identified for aircraft engine fluid connections. The use of an AN924 nut on a bulkhead universal fitting installed in a port became inactive for design in 1975 via MS33566. Refer to the attached excerpt from MS33566.

Previously approved installations using an AN924 nut that have acceptable in-service performance remain approved and remain acceptable. While acceptable performance of the AN924-nut on a bulkhead universal fitting installed in a port in low pressure hydraulic systems is known to have been achieved, un-acceptable performance in medium or high pressure systems is expected. Refer to ARP-4752 Aerospace – Design-and-Installation-of-Commercial-Transport-Aircraft-Hydraulic-Systems and AS4716 (R) Gland Design, O-Ring and Other Elastomeric Seals for additional seal information and general rule information that o-rings operating above 1500 psi should utilize backup rings. Installations of an AN924 nut on a bulkhead universal fitting installed in a port without acceptable in-service performance warrants review and consideration for a design change.

MS21344 installations and MS33566 installations (with AN6289 nut with MS28773 backup retainer) of a bulkhead universal fitting in a port is accepted by the FAA as a standard design for fluid pressures up to 3000 psi. Fitting design evolution continues. AS33566 retains the use of bulkhead universal fittings with an AN6289 nut and MS28773 retainer into a port and consequently is an accepted standard design. The FAA has also received reports that AS5440 includes information for the design authority to preempt the use of bulkhead universal fittings due to their problematic service history. Refer to AS5440.

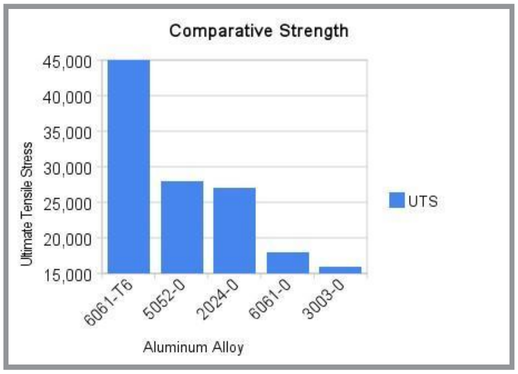
Comparison of Tube Strength for Common Small Aircraft Tubing

Design for Strength

Comparative Tube Strength, 6061,5052,2024,6061,3003

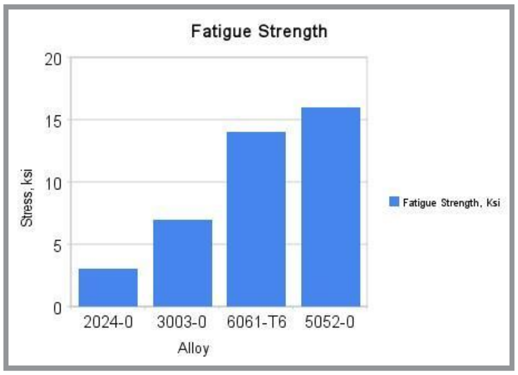
Design for Endurance

Since aircraft are vibrating creatures, fatigue strength is also a limiting factor.

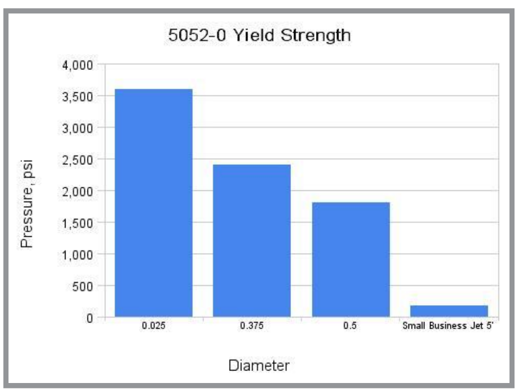


Tube Fatigue Strength

Most tubing-failures on aircraft are caused by fatigue. Tubing on aircraft vibrates. How well your tubing endures when subjected to load reversals, impulses, and vibration is called "fatigue strength". Of the three popular tubing types (3003-0, 6061-0, 5052-0), 5052-0 has the best fatigue strength.



Originally aircraft used soft copper-tubing. There is even some of this still around. Although copper was strong enough, it was replaced with aluminum and stainless tube because of the high fatigue failures of copper. For lower pressures, 5052-0 became the tubing of choice because it has the best fatigue strength of any of the non heat-treat aluminum alloys. See "Fatigue Failures of Copper Alloy Fuel", AWB 28-007



--editorial--
Copper tubing on older aircraft should be removed and replaced with 5052-0 before it breaks. There is no warning when copper tubing breaks. One cannot "inspect" it and declare it ok. Another limitation on the use of copper tubing in aircraft engine compartments is that copper strength decreases rapidly with temperature.

Some experimental and light-sport aircraft have hydraulic and fuel lines built with 6061-0 or 3003-0-tubing. Low ultimate strength and low fatigue strength provide a narrow safety margin in dynamic (vibration or impulse) applications. Take extra care in clamping and preventing tube vibration. The aircraft industry's long experience with copper tubing failures proved the importance of fatigue strength. 5052-0 has higher strength and higher fatigue strength at a small price difference. Both 5052-0, 3003 have the same Cold Workability Rating of A (easy to work with). 6061-T6 has a far lower rating of C. "It hasn't failed yet," was the attitude at NASA that essentially led to both of the Space Shuttle disasters; the complacency arises from skirting the line and surviving. But the law of large numbers will eventually get you.

The aluminum hydraulic lines on the Cessna-404 have experienced 5 reported failures due to metal fatigue. For the mechanic, this means that these lines cannot be inspected for fatigue failure. They will not show fatigue stress before failure. A replacement interval is the only method of prevening failure. The old adage that "if it flew in it will fly out" only works until the next failure. See NTSB Safety Board Recommendation A-83-1-2. Metal fluid lines in aircraft subject to vibration have a potential to fail due to metal fatigue. Using the proper alloy tube, combined with good fabrication techniques, and proper clamping, and hard-time replacement interval is the only protection from sudden failure due to metal fatigue.

Diameter Effects

The larger the tubing diameter, the less pressure it can withstand A 1/4 inch (0.025) aluminum tubing can hold 3,500 psi of pressure. The same aluminum tubing, but in 1/2 inch can only hold 1,800 psi. If we made a business jet pressurized fuselage out of the same tubing, it could only handle 182 psi.

When working with large pressure vessels, such as aircraft fuselage, don't be fooled by the low pressures. Because of their large size, these pressure vessels contain a lot of energy.

Don't forget the bulkhead. The bulkhead constains the fuselage skin, sucking up the load. A good lesson to learn is why the rear bulkhead failed on Japan Airline Flight 123.

Tubing and hose can be thought of as cylindrical thin-walled pressure-vessels. *

The strength of thin walled pressure vessels is determined by: 1. The material strength 2. The wall thickness, and 3. The size of the tubing.

The formula is: strength, psi = yield*(wall thickness/radius)

This last item, tubing size, is unusual. One can understand how strength is related to how strong the material is and how thick it is but size (radius)? The relationship between tubing size and strength is inverse; the larger the tube diameter the less strength it has. When you look at pressure ratings for tubing and hose you will notice that for the same hose, maximum recommended operating pressure goes down as the size goes up.

You can use this property to your advantage. For example, you might have a choice of tubing or hose size for a particular application. Everything else being equal, a smaller diameter line holds more pressure than a larger diameter line. Another advantage is that a smaller size weights less.

Inspection: When you inspect a hose or line, you are inspecting a pressure vessel. As with all pressure vessels, they should be protected from damage that reduces the wall strength. Inspect for nicks, cuts, chafing, and corrosion. Make sure that the line does not vibrate.

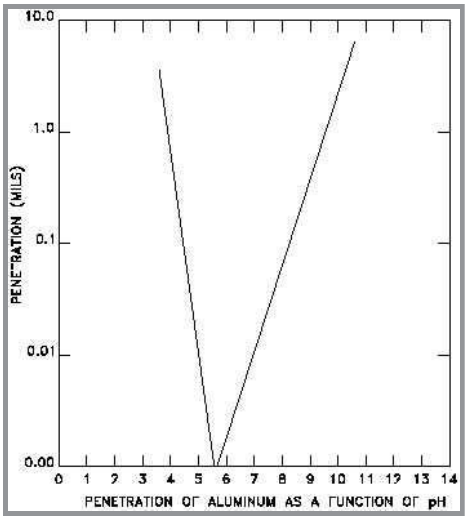
*Pressurized aircraft are also pressure vessels.

Slick Magneto Timing Light Flicker

When timing my slick magnetos I noticed that when the timing light came on and I rotated the prop just a little further the light went out as it should and if I bumped the prop again the light came back on again. What do you think the problem is?

A little dirt or oil on the point surfaces; or a bit of point surface erosion like what is shown in the picture below. A little flicker of the light is probably OK. More and you might need to clean or replace the points.

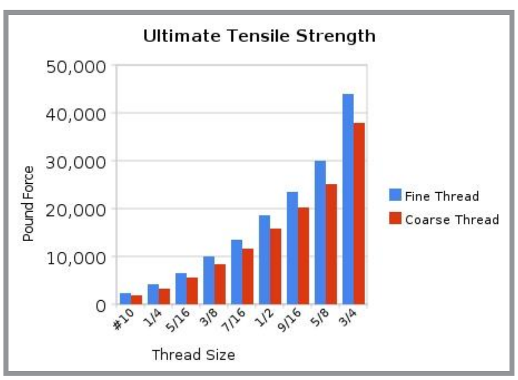
Aluminum Corrosion Penetration as a Function of pH



Aluminum Corrosion Penetration as a function of pH

Possibly the best corrosion prevention for aluminum is a neutral pH water wash to eliminate build-up of alkaline salts and then control of pH in the range of 4.0 to 8.5. The protective oxide film that protects aluminum from corrosion is stable and naturally self-renewing. Many cleaners are either alkaline or acidic (citrus based). Soapy water is highly alkaline. At pH values greater than 10, the oxide film starts to dissolve, resulting in rapid corrosion unless controlled by inhibitors.

Coarse Thread vs Fine Thread Strength



Thread Strength Comparison - Fine vs Coarse

Aircraft generally use fine thread fasteners due to their stronger strength. Coarse threads are used when threaded into aluminum or cast iron because the finer threads tend to strip more easily in these materials. The chart above is based on MIL-B-6812E Table II and 125,000 psi UTS.

Hydrogen Embrittlement

"The treacherous and capricious qualities of steel increase with its tensile strength"

652541 nut used on Continental TSIO-520M engine

It is not uncommon to have decorative engine hardware cadmium plated and "oven-

Process	Hydrogen Embrittlement Risk
Solvent degrease	none
Alkali degrease	none
Electro-clean	some
Acid de-rust	high
Alkali de-rust	low
Abrasive clean	none
Phosphate	medium
Electro-plating (acid type)	medium
Electro-plating (alkaline type)	high
Hot-dip galvanizing	medium
mechanical zinc plating	none
Paint strippers, acid	high
Paint strippers, alkaline	none
Paint strippers, benzyl alcohol	medium

baked" during overhaul. Extreme caution is advised. A particular hazard of cadmium-plating high strength steels is the absorption of hydrogen into the base metal. This hazard is countered by baking the parts after plating.

The baking process is critical. Shown above is a hydrogen embrittled nut failure on an aircraft engine. Even though controls were in place, the nuts still failed. Not only is oven temperature and time important, but also the distribution of heat throughout the batch of parts. Oven bake shall occur within four hours of plating and for types II and shall be done before application of supplementary coatings.

Since high-strength steel parts are subject to hydrogen-embrittlement during any plating process they should not be plated unless proper engineering and quality controls have been established and approved. Per T.O.1-1A-9, "All steel parts having a hardness of Rockwell C40 (180,000 PSI) and higher shall be baked at 375 +-25 degrees F. for three hours minimum. SAE-J1648 states: "It may be necessary to provide coatings other than electroplating for fasteners with hardness above 40 HRC"

All steel parts having an ultimate tensile strength of 220,000 PSI or above shall not be plated, unless otherwise specified. When permission is granted, a low embrittlement cadmium plating bath shall be used. Federal-Specifications-QQ-P-416 should be used for cadmium plate requirements. Critical parts should be magnafluxed after plating."

Years ago, the standard was to oven bake for four hours. This was found to be insufficient and the standard changed (2006, but adopted in the 1980's) is that "cadmium-plated parts must be **baked at 375 degrees F. for 23 hours**, within two hours after plating, to prevent hydrogen embrittlement."

As Cadmium plating is being phased out due to environmental concerns, zinc is often specified as an alternative coating. However, as Lycoming found out, substituting Cadmium for Zinc can lead to disaster. Zinc plating can also lead to hydrogen-assisted cracking. A change from a Cadmium plated crankshaft gear bolt part number STD-2209 to a Zinc-plated-bolt resulted in several aircraft accidents, at least one with multiple fatalities (NTSB IAD02FA091). Several Airworthiness-Directives were issued to remove the Zinc plated bolts and replace them with Cadmium plated ones (AD2002-23-06, AD2002-20-51).

Hydrogen embrittlement and hydrogen-assisted cracking remains difficult to control and predict. There is increasing use of mechanical applied zinc coatings that eliminate the plating process and the resultant hydrogen problem during manufacturer. For further information see the following SAE publication: SAE AMS 2759/9B "Hydrogen-Embrittlement-Relief (Baking) of Steel Parts"

---Example----

An interesting example of hydrogen embrittlement is the fatal accident of a Bell-206 helicopter in British-Columbia in June of 2000. The screws in the fuel control unit broke due to hydrogen embrittlement. The repair facility replaced the screws during overhaul with standard AN503 screws. Ordinarily hydrogen embrittlement is not a problem with these screws because the rated tensile strength is 125,000 psi, (862 MPa) well under the 145,000 psi where hydrogen embrittlement becomes a problem.

However, the screws tested much stronger than they should have been due to improper heat treatment. The cadmium plating applied to the screws then introduced hydrogen into the steel. If the screws had been manufactured to the proper tensile stress, they would not have failed and the fatal accident would not have occurred. This accident was caused by screws that were stronger than they should have been. In fact, the entire lot of screws were non-conforming.

ref. Transportation-Safety-Board-of-Canada, Aviation-Investigative-Report, AW00W0105

----Example----

Another interesting example of hydrogen embrittlement failure is when Lycoming changed their crankshaft-gear retaining bolt STD-2209 to zinc-plating from cadmium-plating. This one bolt in the engine is a "Jesus" bolt, in that if it breaks, the engine quits. Unknown to Lycoming at the time, zinc plated bolts with a hardness exceeding RC 39 have a history of hydrogen embrittlement failure. Soon afterward random bolt failures started to occur - a typical trade-mark of hydrogen embrittlement failure. Lycoming didn't heed the basic rule of aircraft design: "no single failure shall have a catastrophic effect." See Lycoming-Service-Bulletin-No.-554.

As a general advise, avoid ultrahigh strength carbon steels as they are too susceptible to corrosion and hydrogen embrittlement. Here is a quote from: SAE 820122 Delayed-Fracture of Class 12.8 Bolts in Automotive-Rear-Suspensions
"After over two years service in the "snow belt", class 12.8 bolts in GM "A" car rear suspensions began to fail, leading to the recall of 6.4 millions cars. Analysis of the failures showed that the cause was corrosion induced hydrogen assisted cracking."

----Example----

Beech tried using high-strength-H-11 bolts in their aircraft with catastrophic results (NTSB-Safety-Recomendation-A-82-32 and -33) because of bolt failure due to stress corrosion failure. Bolts made from this alloy are popular for automotive performance engines. Even being described in one ad as "Extreme Duty"! FAA Advisory-Circular-AC20-127 calls for the replacement of SAE H11 bolts in primary structure on all aircraft. "The service history of H11 bolts used in primary structure indicates a higher than normal failure rate. These failures are attributed to stress corrosion-cracking and may become a safety problem. The use of H11 bolts in primary structure is therefore discouraged and should not be considered for use on new type design aircraft." Primary structure is defined as that structure that contributes significantly to the carrying of flight, ground, or pressurization loads, and whose integrity is essential in maintaining the overall structural integrity of the airplane.

As a mechanic, inspect and replace any high-strength bolts showing corrosion. Not only do these high-strength bolts suffer from low energy of fracture (brittle), but the act of corrosion itself may cause cathodic hydrogen absorption arising.

"The worst sin in an engineering material is not lack of strength or lack of stiffness,..., but lack of toughness, that is to say, lack of resistance to the propagation of cracks"

*1. Some sources give 130 ksi or greater as the start of hydrogen embrittlement concern. One such source is the Navy SUBMARINE-FASTENING-CRITERIA (NON-NUCLEAR) TECHNICAL MANUAL S9505-AM-GYD-010 paragraph 3-20 "Preloading"

*2. Navy SUBMARINE FASTENING CRITERIA (NON-NUCLEAR) TECHNICAL MANUAL S9505-AM-GYD-010 paragraph 3-20 "Preloading"

Hydrogen Embrittlement Testing - Stress Durability
"If coated, the following grades of steel fasteners shall be subjected to hydrogen embrittlement stress durability test in accordance with MIL-STD-1312, test no. 5: Grade 8, 400 series corrosion resistant steels with HT heat treatment, grade 630 corrosion resistant steel, and socket head cap screws grades 574 and 4340 . The fasteners shall be held under load for 48 hours." MIL-S-1222H 4.4.8

Hydrogen Embrittlement Risk due to Cleaning Methods

When to Use a Washer

Flat Washer with Split Lock

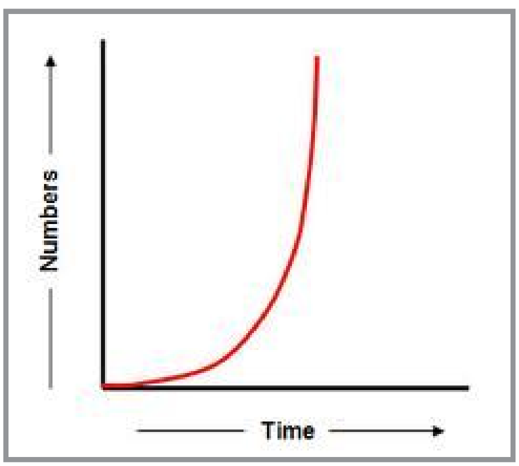
A washer is often used under the nut or bolt, whichever is turned during the tightening operation. When both nut and bolt can be turned, washers are commonly used under both. All washers shall be made from a material which is capable of accepting the peak fastener load without deformation.
A washer can provide multiple functions, the two most important ones are: 1. Spreads the clamping force over a larger area to avoid compressive yielding, and 2. Hard, smooth, consistent material for good preload (clamping) control.

Other functions are to: 1. Prevent galling of the nut face or surface during tightening. 2. Reducing the external load carried by the bolt by increasing the effective pressure area. This stiffens the joint members and the stiffer the joint members the smaller the fraction of external load the bolt will "see". 3. Prevent galvanic corrosion by separating dissimilar metals. Example would be using an aluminum washer under a steel bolt head tightened against an aluminum crankcase. Any galvanic corrosion occurs between the washer and bolt head rather than between the crankcase and bolt head. A washer is cheaper to replace then the crankcase. 4. Increase energy stored in bolt by using a longer bolt. This helps retain clamping force. 5. Adjusting grip length.

Washer compressive strength must be matched to the bolt/nut clamping force. WASHER compressive strength MUST be matched to the BOLT/NUT combination! Pictured above is a low-yield strength hardware store washer placed under a propeller bolt. Low-yield strength washers that score/crush in-service under high strength BOLT heads or NUTS, will relieves clamping force, eventually resulting in propeller detachment during operation.
Aircraft Accessory as Designed!
When NOT to use a washer. The built-in washer under the head of a flange head bolt acts to distribute the clamping load over a greater area. No washer is needed or desired. This aircraft starter is assembled with washers under the flanged bolt head. Notice that the bolt head overhangs the washer more on the left side.

Camshaft Lobe Pitting Evaluation

I've enjoyed reading your articles very much. They are very informative and helpful. I have an additional question regarding cam Spalling. I have a Lycoming IO360 A1A that we removed the cylinders due to a broken ring. While inspecting the cam we noticed minor Spalling on one of the lobes. All the lifters and other lobes look good. The spalling is limited to a single line that runs across the one lobe. The attached picture is not of my actual lobe, but the area circled in RED is representive of the level of damage on my lobe. I'm trying to make an informed decision on to either place the overhauled cylinders back on or major the engine. Can you provide any insight on how long it will be before my cam deteriorates to the point it is no longer airworthy? If this cam will last another 400 hrs I would prefer to leave it alone for now, but if it is only going to last 50 -100 hours I would go ahead and major the engine. Any advice will be very much appreciated.



Camshaft Lobe Pitting Mike,

The engine manufacturer should be consulted as to the limitations for continued airworthiness.
Assuming the cam follower face is OK? Did you reach in with your hand and rub your fingernail across the surface to detect pitting?
I want you to look at something else on the cam lobe; do you have polishing wear across the entire lobe - end-to-end? Using your exemplar picture notice how the lob surface is shinny from edge to edge. If it has then I would replace the camshaft. The reason I say this is that lobe wear leads to a reduction in power which is an airworthy condition.

Slight pitting does not hinder the proper function of the camshaft but it will progress until it does at an indeterminate rate; start budgeting. Along the way I would use the oil filter inspection technique (originally developed by Lycoming) to detect cam lobe trauma. Do not cut-out the oil filter media but place it into a can with solvent and rinse. Use a toothbrush to lightly scrub between the pleats so any debris is removed from the pleats. Next pour the solvent through a coffee filter and allow to dry. Take a small magnet under the filter paper move all of the magnetic particles from the other debris. If you have enough small metal bits to cover the end of a stick magnet then your lobes and tappets are in a state of active disintegration and the problem needs to be corrected before further operation. Hopefully, you will have none or maybe a stray bit or two indicating that the lobes and tappets have stabilized.
I don't know if this camshaft will last 50, 150, or 400 hours. I would guess that the wear (damage) rate follows roughly an exponential curve. Long duration of little damage and then as the surface starts to pit the damage rate accelerates. Therefore, inspection intervals should be progressively shortened once the onset of pitting is detected.

Bulkhead Fitting Installation into Aircraft O-Ring Port

Aircraft AND10050 Port with Bulkhead Fitting **Low Pressure - Other Than Hydraulic and Pneumatic** 1. Assemble AN924 nut onto fitting end and run all the way back to clear fitting groove.
2. Coat male threads and O-ring sparingly with system lubricant.
3. Hold O-ring firmly against the top of the threaded section of the fitting and run nut down until it contacts the O-ring.

Position O-ring and Nut as Shown 4. Turn the fitting into the AND10050 boss and, at the same time, keep the AN929 nut turning with the fitting until the O-ring contacts the boss. The point can be determined by a sudden increase in torque.
Turn the fitting O-ring contacts the boss 5. Continue to screw fitting into the boss for another 180 degrees. Any further positioning of the fitting must be accomplished by turning the fitting in up to an aditional 270 degrees or by backing out up to 10 degrees. Keep the AN924 nut turning with the fitting to prevent cutting the gasket with the fitting thread.
Fitting installed
6. Tighten locknut lightly
7. Now assemble flared tube to nipple end of fitting.
8. Now tighten lock nut against boss

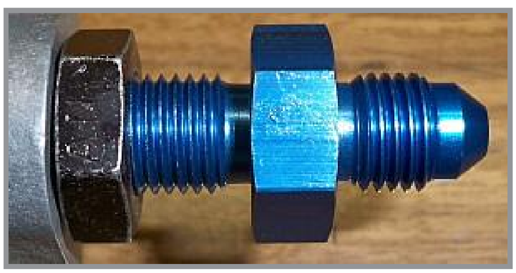
High Pressure or Hydraulic System Installation

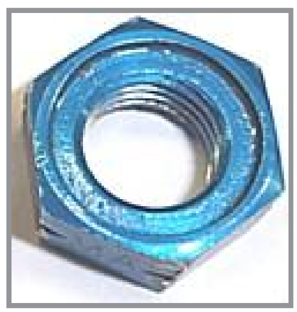
AN6289 Nut

This process uses a different lock nut, a AN6289 nut with a groove for a anti-extrusion device.

Backup Ring (anti-extrusion)

The above description follows AND10064 "Fittings, Installation of Flared Tube, Straight Threaded Connectors" Also reference FAA Special Airworthiness Information Bulletin, SAIB: CE-07-46 dated September 6, 2007 for important installation background and details.





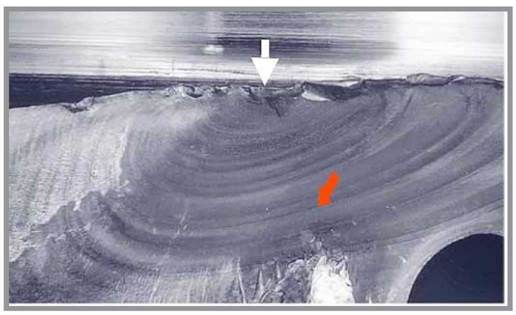
Aircraft Fuel Flow Transducers - Hose Suggestions and Warnings

Two Rules of Hose Installation that are often Violated when Installing Aircraft Fuel Flow Transducers

1. Fittings should not be used as a bracket.
The fitting should not see any forces (from the overhang weight of the transducer or movement or vibration). A hose should be installed with a slight loop or radius to absorb any movement or thermal expansion or contraction. Some suggest using steel fittings instead of the traditional aluminum AN fittings because they are stronger. If you intend to use the fitting as a bracket then yes, by all means use steel. If you intent to use the fitting as a fitting then steel just adds weight. A copper-based alloy fitting is the ideal fitting to use in aluminum bosses; as a substitute, aluminum.

2. A hose should have a loop or radius. It should not stretch straight from fitting-to-fitting.
A short straight hose is a rigid connection. Any thermal expansion, contraction; movement is transfered to the fitting, thereby violating rule #1 above.

Beech Marks, Fatigue Failure, and High Compression Pistons



"Designs will fail if subjected to overload...that's just the nature of efficient design--they might not fail immediately; but some statistically determined time in the future--they will not fail from overload but from a more insidious process called fatigue."

Lycoming Crankshaft Fillet - Fatigue Failure Beech Marks are a sign that a crack progressed across the part and failure was due to fatigue. They are shown in the picture at the red arrow. The white arrow shows the crack initiation point.

Fatigue occurs when the metal is subjected to repeated or alternating stresses not exceeding the material's static yield strength. A fatigue failure is a failure due to repeated stress BELOW the material or parts ultimate tensile stress. A part can operate normally and then suddenly fail in fatigue if cyclic stresses are above the fatigue strength of the metal.

Even more interesting is that fatigue strength is a probability based on statistics and not one set value. The actual fatigue strength of a particular part might be less or might be more. There is no way of knowing unless you test it to failure.

So what has this to do with high compression pistons? Anytime you increase engine power above what the engine was designed for you assume that the original design is inefficient -- built stronger than need be and this extra strength caused by design ignorance is just waiting for some smart person to exploit.

But could it be that the original design is competent. That the engineer designed for endurance; the designer knew that statistically some of the parts would be slightly weaker in fatigue so he designed beyond 3 sigma as he had to be sure your crankshaft would not

fail; that he designed for an infinite fatigue life by purposely limiting the stress.
So how do you know if the high compression pistons place the fatigue life into the finite part of the fatigue curve without doing the stress analysis? You don't. Will it fail? You don't know. When will it fail? You don't know. Engine horsepower output overtime (endurance) can be no greater than crankshaft fillet strength.
Years ago when I asked a Lycoming engineer what he thought of a popular engine modification he said: 'ask me in 5 years; but of course it might fail in the 6th year." Who knows without the stress analysis.

19th century economist Frederich Bastiat:

"This explains the fatally grievous condition of mankind. Ignorance surrounds its cradle: then its actions are determined by their first consequences, the only ones which, in its first stage, it can see. It is only in the long run that it learns to take account of the others. It has to learn this lesson from two very different masters—experience and foresight. Experience teaches effectually, but brutally. It makes us acquainted with all the effects of an action, by causing us to feel them; and we cannot fail to finish by knowing that fire burns, if we have burned ourselves. For this rough teacher, I should like, if possible, to substitute a more gentle one. I mean Foresight."
Continental IO-520 thrown connecting rod
To summarize: it is better to learn from foresight than experience.

Don't Mix your Metals

Stainless steel hardware (rivets, bolts, screws) installed into an aluminum fitting creates a potential for dissimilar metals (galvanic) corrosion.
Corrosion Pit from galvanic corrosion
Leaking hydraulic line from aircraft brake system caused by galvanic corrosion. Aircraft brake systems are drenched in electrolyte (dirty water) so extra caution is advised when mixing metals. Notice that the gap between the tubing and sleeve can trap moisture into the crevice.
Stainless Steel sleeve on aluminum fitting = galvanic corrosion

"Stainless steel parts are cadmium plated and primed if they are attached to aluminum or alloy steel parts." Boeing Aircraft Aero No. 07 "Design for Corrosion Control"

"Aluminum structure shall be insulated from non-aluminum fasteners" Navy Ships' Technical manual Chapter 075 Fasteners, page 75-59.

"Dangerous corrosion will result if steel, corrosion-resistant steel, Monel, titanium, copper, or iron rivets are used in riveting aluminum structures. Such applications should be confined to extreme emergencies" US Air-Force-Airframe-Repair-Specialists (AFSC 42755), Repair Procedures, page 16.

.**Boeing's Big Recall:** News article from King5 News in Renton Washington November 24, 2008 concerning stainless-steel-nutplates not being coated with cadmium. Now, tens of thousands of others lack an important coating of cadmium. That nearly invisible coating is important because it prevents the stainless steel nutplate from reacting with the airplanes aluminum, which can lead to corrosion. Spirit says the untreated nutplates from one of their suppliers got mixed in with treated plates from another were installed by the thousands. Spirit employees are now inside Boeing plants trying to find and replace the bad nutplates on new jets.

Why this Matters The reason corrosion is such a problem in load bearing structures is that the corrosion pitting provides the perfect nucleation points for fractures to form and propagate from. They must be repaired promptly and properly.

Graphite Lubricants in Aircraft- The Corrosion Potential

Graphite Antiseize

"...shown conclusively that graphite in a resin-bonded solid film lubricant is deleterious from the point of view of corrosion protection provided by the lubricant... To use graphite is to invite corrosion difficulties in the presence of moisture." Rock-Island-Arsenal-Lab, Technical Report, Dry-Lubricants and Corrosion, Prepared for Presentation at the Annual Meeting of the Society of Automotive Engineers, Detroit, Michigan 14-18 January 1963. Francis S. Meade and George P. Murphy, Jr.

.

Aircraft Spark Plug Graphite Antiseize

Graphite and water has been used and recommended for aircraft spark plugs for over 50 years. Other anti-seize that contains metallic particles have been avoided because of the chance that the anti-seize particles may get into the combustion chamber, create a hot spot, and cause destructive pre-ignition.

Years ago mica-anti-seize was commonly used for spark plug anti-seize and it probably has better properties than graphite and water. However, there is a problem in changing anti-seize types; you change the torque tension relationship. Published torque values in aircraft spark plugs are based on using the manufacturer's recommended anti-seize. Use a different type of anti-seize and the required torque to achieve the proper amount of tension will change by an unknown amount.

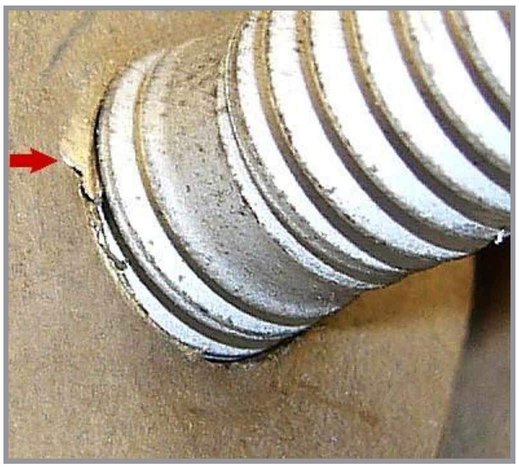
Cleaning spark-plugs using glass-bead shot may remove the nickel plating from the

threads. Now the steel threads are exposed to the water and graphite mixed anti-seize creating a corrosive environment.

When the steel threads rust, their surfaces expands and this causes the spark plug to seize in the threads.

Consideration should be given to using a different type of anti-seize in this special circumstance such as a mica based anti-seize.

Continental Cylinder Stud Design



Continental just makes a better cylinder ...I have no vested interest in Continental and I don't sell their cylinders but I do appreciate good engineering and design...attention to details that I don't see in other "PMA" cylinders.

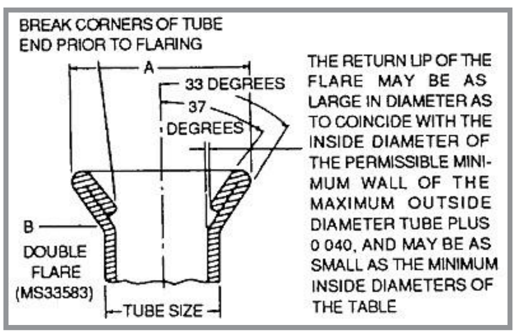
PMA Cylinder Workmanship Notice the stud isn't even straight and the design puts the maximum stress at the surface where it is pulling metal already.

Continental Workmanship Now look at the same stud on a Continental cylinder. Chamfered hole. Notice how the first engaged thread occurs below the surface. Stud is "waisted" - that is a good thing!. Waisting is the reduced diameter in the unthreaded portion of the stud. This diameter is now the same as the root diameter of the thread making the stress evenly distributed throughout the stud.

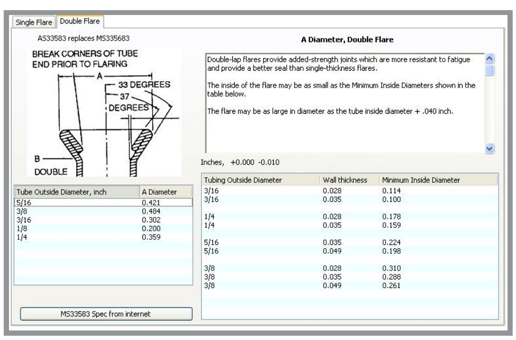
Wasted Cylinder Hold-Down Stud Here is a picture of a waisted cylinder hold-down stud on a Continental. The reduced shank diameter also allows the stud to store more energy as it will stretch more than a non-wasted stud for the same amount of applied tightening torque. This increases fatigue strength and helps prevent joint loosening.

Waisted Cylinder Hold-Down Studs on Continental IO520 engine

Double Flare Tubing



Aircraft Standard MS33583 Double Flare "A double-flare is used on soft aluminum tubing 3/8 inch outside diameter and under, and a single-flare on all other tubing." AC43.131B "FAA Acceptable Methods, Techniques and Practices"



As system pressure increases, tubing joints must be designed to withstand these pressures. 5052-0 is soft tubing and the flare is not strong enough to handle higher pressures. Double flaring reduces cutting of flare by overtightening and failure of tube assembly under operating pressure. A double flare is stronger in fatigue. Except in emergencies, there is no acceptable reason to use a single instead of a double flare where appropriate. That said, in practice, very few flares made by mechanics are double flares, however, this does not make the practice acceptable nor desirable.

A leak-free connection is not the sole measure of an acceptable flare. The proper radius at "B", and no nicks or other damge is required for a durable connection that won't break later in service. This is why using a 45 degree flaring tool and then mashing the flare to a 37 degree with the "B" nut may produce a leak-free connection for the moment but does not produce a safe, durable connection.

Construction Standards per MS33583

Double Flare Radius. Screenshot from Mechanic's Toolbox Software

B Radius

0 1 2

Tube Size Outside Diameter, Inch B Radius, Inch

1/8 0.032
3/16 0.032
1/4 0.032
5/16 0.032
3/8 0.046
1/2 0.062
5/8 0.062
3/4 0.062
1 0.093
1-1/4 0.093
1-1/2 0.109
1-3/4 0.109
2 0.109
2-1/2 0.109
3 0.109

Measuring B radius Measuring B Radius

Clean and Dry Torque

"Clean and Dry" Problem for the Mechanic - Problem for NASA
Is this stud "clean and dry"?
How should it be cleaned?
MIL-HDBK-60 offers guidance
Bolts and studs are often plated with Cadmium, Zinc, and other coatings that have published "K" (friction) factors. Torquing the bolt using a "clean-and-dry" specification produces a reasonably accurate amount of tension based on these 'K" factors.
With new bolts and studs there are no cleaning issues for the mechanic as the bolt or stud is received in the "clean and dry" condition. What about old used bolts and studs? They are not received in the "clean and dry" condition. In what manner should the mechanic clean the surfaces? Should a wire brush be used to clean old thread locking compound from the threads?
Plating may be damaged or worn; threads might be damaged; rust, paint, and adhesives

might be stuck in the threads. Cleaning often involves whatever is handy, such as a wire wheel or wire brush. Whatever plating is left in the threads might be worn off during cleaning. The cleaning compound might have a big impact on thread friction. 1

Threads create 50% of the friction resisting torque, the bearing surfaces create the other 50%. Does "clean and dry" apply to only the bolt threads? Or does it apply also to the bearing surfaces?

A "clean and dry" torque specification for used bolts and studs without specific cleaning and inspecting directions is deficient. The "K" factor on some old used bolt and stud might be almost anything and vary from bolt to bolt. Not only engineers but mechanics should be aware of this limitation.

NASA found this out during testing of a model wing in their 8' Transonic-pressure-tunnel when the flap peeled away from the wing, broke free, and proceeded down the tunnel. Engineers had specified a "clean and dry" torque. This was quite impossible as the assembly directions also specified that a liquid thread locking compound be applied to the bolt during assembly.

The particular bolt was often removed and reinstalled during testing. What the technicians at NASA did was re-apply thread locking compound to the bolt each time it was installed. NASA lost the model wing when the bolt backed-out. NASA's "Lessons Learned" document states quite simply: It is impossible to predict torque value on screws after repeated applications of "a thread-locking compound".

Why would a "clean and dry" specification be used? Clean and dry threads and bearing surfaces have greater friction than lubricated surfaces. Friction helps prevent the bolt or nut from loosening and backing-off. Clean and dry, uses friction to our advantage and can be an aid keeping fasteners tight.

MIL-HDBK-60-THREADED-FASTENERS - TIGHTENING TO PROPER TENSION offers this description of "dry": "So-called "dry" threads refer to threads where no lubricant is applied. Some residual machine oil is assumed. If all lubricant is removed by solvent, coefficient of friction is inconsistent and often very high unless a plating or other film is acting as a lubricant. Severe galling may also result from lubricant-free surface conditions."

It appears from the above quotation that a proper torque condition statement is "dry threads" rather than stating "clean and dry".

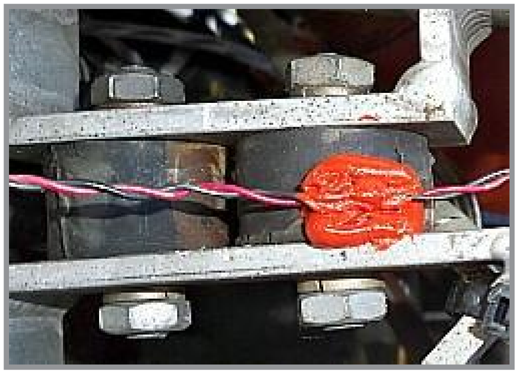
1. "Failure-of-bolts-in-helicopter main rotor drive plate assembly due to improper application of lubricant" by N. Eliaz, G. Gheorghiu, H. Sheinkopf, O. Levi, G. Shemesh, A. Mordecai, H. Artzi, Published in Engineering Failure Analysis #10, 443-451.

Aircraft Wire Inspection

Rats!

ASTM Standard F 2696 08 "Standard Practice for Inspection of Airplane Electrical Wiring Systems" is an excellent resource for developing a wire inspection system. Some comments I have are below:

"The principal technique for inspecting aviation and spacecraft-wiring components used to date remains visual inspection. These inspections are unable to detect all extant flaws and are subject to discrepancies and errors. Moreover, these tests are intrusive, since brittle wire bundles are frequently moved to access more remote wiring components and



can result in further damage to already cracked insulation."

Source: *NONDESTRUCTIVE EVALUATION OF AROMATIC-POLYIMIDE-INSULATED AIRCRAFT AND SPACECRAFT WIRING. E.J. Tucholski, Phusics Department, U.S. Naval Academy, Annapolis, MD*

It should not be expected that the mechanic will be able to detect all aircraft wiring faults through visual inspection. It's the responsibility of the FAA and aircraft engineers to develope suitable inspection tools or apply age control limitations to aircraft wiring. The problem of "aging aircraft wiring" is an age problem and not a maintenance problem.

"When a failure could have catastrophic results, it is not appropriate to rely on maintenance and inspection intervention to prevent the failure from occurring if a practicable design alternative could eliminate the catastrophic effects of the failure mode." Quote from *NATIONAL TRANSPORTATION SAFETY BOARD Public Meeting of December 10, 2002 Abstract of Aviation Accident Report Alaska-Airlines-Flight-261, MD-83, N963AS NTSB/AAR-02/01*

Wire Support using red RTV

Inspection tips:

High voltage and low voltage fuel sensor wires should not be mixed in the same bundle. Damage to the wire bundle could allow high voltage to enter the fuel tank. Recommendation resulting from TWA-Fligh- 800 747 fuel-tank-explosion

No wiring is routed in proximity to oxygen, fuel, and hydraulic lines or critical flight control cables. ASTM F2696-08 reads in part: "where practical, route electrical wires and cables above fluid lines and provide a 6 inch (15 cm) separation from any flammable liquid, fuel, or oxygen line, fuel tank wall, or other low voltage wiring that enters a fuel tank and requires electrical isolation to prevent an ignition hazard. Where this 6 inch cannot be maintained then wiring should be closely clamped and rigidly supported to avoid contact even assuming a broken wire or missing clamp.

Protect the wire from contamination by fluids (including corrosion inhibiting compounds), flammable lint, metal shavings, or other debris. Hard materials can work their way into the wire bundle and with vibration penetrate the insulation causing electrical shorts. Fluids can soften or crack the insulation. Water and dirt become slightly conductive and lead to arc-failures.

Unless advised otherwise in the maintance manual, do not mix wire insulation types in the same bundle because insulation of different hardness may create chafing damage in vibration areas.

Wires and cables are supported by suitable clamps, grommets, or other devices at intervals of not more than 24 inches (61 cm).

Wires must be grouped, routed and spaced so that damage to essential circuits will be minimized if there are faults in heavy current-carrying cables. The objective is to minimize the impact of the failure of a heavy current-carrying cable on any essential system wiring.

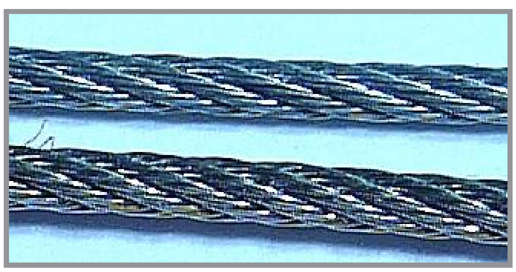
Protect the wires from moisture and high temperatures; these cause wire insulation to age and crack.

The minimum radii for bends in wire groups or bundles shall not be less than ten times the outside diameter of their largest wire, except at the terminal strips where wires break out at terminations or reverse direction in a bundle.

Due to cold flow phenomena of teflon insulataion used in MIL-W-22759 wire, it is advised NOT to route teflon insulated wires over sharp edges and tight turns, or apply tight tie wraps to cable assemblies. Cold flow or creep is the slow movement of the insulation when under a steady-state stress. The old practice of using soft Koroseal-lacing (rubber lacing) to tie wire bundles together is much less damaging then using hard plastic tie-raps.

If you are developing a wire inspection standard for your business I would suggest that you review ASTM Specification F2799-9 "Standard Practice for Maintenance of Airplane Electrical Wiring Systems." and ASTM Specification F2799-8 "Standard Practice for Inspection of Airplane Electrical Wiring Systems" These are excellent documents for any shop and are well worth the price.

Aircraft Control Cable - Stainless or Galvanized?



Aircraft Control Cable
Galvanized on top and Stainless on bottom

"A general service history has shown the use of stainless steel cables in aircraft control systems results in premature wear and has been a factor in minor incidences as well as catastrophic failure. A current trend is underway in the aviation industry to move away from the use of stainless steel cable for primary flight control applications, except where marine operations are performed." FAA Special Airworthiness Information Bulletin CE-12-01 Dated October 24, 2011.

Frayed stainless steel control cable is suspect in a Twin-Otter crash killing 14 passengers in Tahiti in August of 2007.
General aviation aircraft generally use control cable made from either stainless steel or galvanized steel. Each type has its advantages and disadvantages. Generally;

- Galvanized rope is stronger.
- Galvanized rope has greater fatigue strength.
- Galvanized rope has less wear.
- Galvanized rope is easier to inspect for corrosion damage.
- Per FAA CE-12-01:
- Stainless steel is more corrosion resistant.
- Stainless steel has considerably less service life due to high wear.
- Stainless steel cannot be inspected for corrosion damage.

- Stainless steel is stiffer and has lower bending fatigue resistance - important in flight control systems
- Stainless steel has a higher friction coefficient that results in increased wear every time the cable is flexed.
- Stainless steel becomes more stiff, leading to increased abrasion wear in the inside as well as the outside of the cable

The poor wear resistance of stainless steel rope has resulted in aircraft control problems. More frequent inspections are required. For more information on this subject reference: Special-Airworthiness-Information-Bulletin:-SAIB CE-01-30, July 11, 2001. For 172S airplanes see FAA SAIB: CE-11-3. also CE-11-36, Piper Service Bulletin 1048.

There are several reasons why stainless wears more than galvanized steel when used on flight controls:
The bending of a wire rope causes the individual wire stands to not only bend but to rub against one another. Galvanizing is a natural lubricant. For example, galvanized threads have a lower friction (K) factor then plain steel. The individual wires can easily move about with very little friction and wear. Stainless steel on the other hand has high friction and has a reputation for seizing and galling when rubbed together. Every time the wire rope is flexed, the stainless wires rub together. High friction creates high wear.

There are several methods of reducing wear and increasing fatigue resistance in a wire rope. Wear resistance can be increased by changing how the wire stands are wound. In the picture above the individual wires are horizontal (parallel to the axis of the rope). This is called "right regular lay" and is the standard lay. Another method of winding the wire stands is so that they form an angle to the axis of the rope. This is called "lang lay". Lang lay increases fatigue strength and abrasion resistance without any decrease in ultimate strength. Another method of changing the wire characteristics of fatigue strength,. abrasion resistance, and flexibility is to use wires of different diameters. For example, Douglas-Specification DMS2192 calls for a Warrington Seal (IWRC) construction. This type of wire rope has larger wires on the outside and and smaller wires on the inside.

There are other wire rope designs that the engineer can call for to optimize specific performance goals. This is why when we replace wire rope we should make sure that the replacement meets the original manufacturer's specifications.

Galvanized Vs Stainless - who uses what?
As of 2004, Boeing uses practically no stainless steel cables. They use the Tin over Zinc variety of carbon steel cable in their primary flight control cables.

Stainless Steel Stress Corrosion Cracking - Primer for Aircraft Mec...

Stress Corrosion Cracking

What does an indoor swimming-pool-roof-collapse in Switzerland that kills 14 people, an aileron failure in a Bonanza, and rock-climbing-bolts that break when slightly tapped have in common?

- Failures occurred in parts made from 300 series (austenitic) stainless steel. The most commonly used grade.
- Parts were exposed to salts and chlorides
- Parts were stressed in tension.
- Engineering standards and tests at the time said it couldn't happen.

Seven aircraft have lost flight control because the stainless control cable terminals cracked due to corrosion. The turnbuckle terminals (part number MS21250 or AN669) are made from 303 stainless - a common grade of stainless. This type of terminal is used on most general aviation aircraft and helicopters. Piper reportedly manufactured 51,600 airplanes containing these terminals. One Navy aircraft suffered a failure. There is also a long history of turnbuckle breakage in sailboats.

When chloride-salts get into crevices where there is a lack of oxygen, pits form in the stainless and the part eventually breaks from the inside out. This is called Chloride stress-corrosion cracking. Since the corrosion forms pits inside crevices, the part may look perfectly good from the outside. In the case of the turnbuckle terminals, general corrosion pits were found on the surface of "most" of the broken terminals. Also, in the AN669 series, the safety wire wrapped over the terminal hid the corrosion pits.

In the case of the rock climbing bolts, they looked fine until lightly tapped and broke flush with the rock face. Pretty scary if you are dangling from one of those bolts. In the roof collapse, the stainless hangars were above the ceiling panels hidden from view. 300 series stainless is now banned in the European Union, Switzerland, and Australia for use in indoor swimming pools when used in safety critical applications. It is still being used on aircraft flight controls!

Stainless steel (especially the common 300 series) does not like chlorides. Chlorides are found in salt water, road salt, and some cleaning solutions such as trichloroethane, and methylene chloride. (trichloroethane is often found in the cleaner portion of dye penetrate cleaners that are used in the aircraft industry to find cracks.) Some insulation material contain chlorides. The worst corrosion combination for stainless steel is low-oxygen and high chlorides as might be found in crevices.

Salt-deposits are hygroscopic, they absorb moisture from the air. When the relative humidity is over 50%, the surface becomes wet and corrosion starts. Wash off any salts that may have been deposited on you're equipment.

Failure Characteristics:

- SCC failures can occur rapidly or very slowly. Inspections or replacement based on time-in-service may not be a useful criteria.
- SCC failures are rapid, complete break of the part. There is no tell-tale bending or sagging.
- Visual inspection has not been helpful in identifying suspect parts before failure.

Best Maintenance Practices:

- It appears that the best maintenance practice is to keep the parts clean so that chlorides don't concentrate on the surfaces.

Best Engineering Practices:

- Use better stainless grades, such as the Superaustenitic or Duplex grades.
- Use shot-peening to improve the SCC resistance. Shot peening is a proven method of improving the SCC resistance in austenitic stainless steel parts.

Other areas to be concerned about:

- Load bearing stainless parts exposed to chlorides where the failure could result in a safety hazard. Some examples might include:
- Aircraft structural parts, such as bolts, turnbuckles, etc. where aircraft are based or operated next to the ocean
- Swimming pool ladders and bolts used on swimming pool slides and diving boards.
- Bolts used on trailer hitches on vehicles next to the ocean or where salt is used on the roads to melt ice.
- Bolts used on road signs next to the ocean or where salt is used on the roads to melt ice.

Aircraft Control Cable - What is it?

The standard for fight-critical aircraft control-cable is MIL-DTL 83420. It is estimated (Defense Daily Network July 27, 2005) that less than 2% of "aircraft control cable sold in the world today meets MIL-DTL-83420. Most of it is what you would find in your local hardware store. Tests performed on non-MIL-DTL-83420 cable concluded that the fatigue strength requirements were rarely met. If your log book entry or sales receipt uses the term "aircraft control cable" then you might be implying that the cable is MIL-DTL-83420 when it is not.

There are two easy identification methods that may help you identify aircraft control cable:

1. All MIL-DTL-83420 contains a two-color tracer filament emended within the cable that identifies the manufacturer,
2. All MIL-DTL-83420 cable sold on a shipping real must contain the identification number of the manufacturing reel. (All MIL-DTL-83420 cable is lubricated with a corrosion inhibitor.)

Aircraft Control Cable Wear

Discussion:

Aircraft devices are designed based on:

1. Strength
2. Endurance

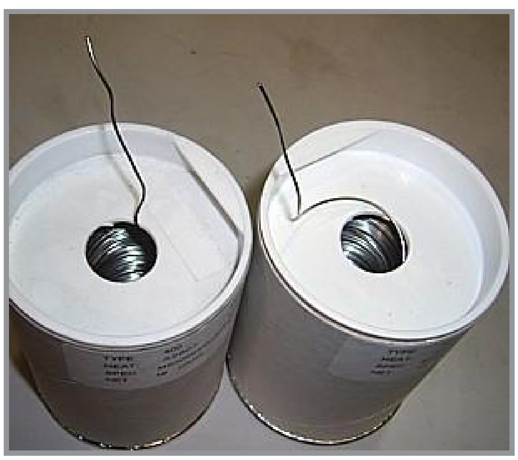
Often we focus only on the strength aspect. "How strong is it? or How many "G's"? One should also ask "For how long? This is called "endurance." Fatigue strength gives us endurance. The principle difference between aircraft and non-aircraft control cable is endurance (fatigue strength). How many times will the cable bend over the pulley before it starts to break (frays)? Fatigue strength is measured in number of cycles at a given load.

One may think incorrectly that fatigue strength is not so important for a lightly loaded aircraft control cable. An interesting example of fatigue strength importance is on the Eagle-Aircraft where the control cables were fraying between 400 and 900 hours in service. In models X-TS150 and 150B, Australian-Airworthiness-Directive-AC/XT-S/2 and CASA #0008 was issued along with Service Bulletins from the aircraft manufacturer to inspect cables for fraying at the pulley. In this instance the fraying was attributed to the small size of the cable-pulley. Although not mentioned in the report, cable fatigue strength is also a factor in cable fatigue failure (fraying).

Another possible cause is the use of stainless steel cable instead of galvanized steel. Stainless steel has high friction and the individual wires can gall as they rub against one another. Galvanizing acts as a lubricant and keeps the steel cable from wearing. Consequently, wear rates on stainless steel cable used where the wires may move - such as rounding a pulley - are far greater with stainless steel. More frequent inspections are required. As of 2004, Boeing uses practically no stainless steel cables. They use the Tin over Zinc variety of carbon steel cable in their primary flight control cables.

A review of Malfunction and Defect reports from several countries seems to show that premature cable fraying is not an isolated event. A fatal Twin-Otter-crash because of worn stainless steel elevator cables in Tahiti prompted BAE, Transports Canada and the European-Agency-for-Air-Safety to ask owners of these aircraft to inspect elevator cables. This is not a new problem. In our relatively lightly loaded control systems, cable fatigue strength and wear rate might be more important than ultimate strength.

Monel Safety Wire - When to Use



Stainless Steel Safety Wire on left - Monel Safety Wire on right

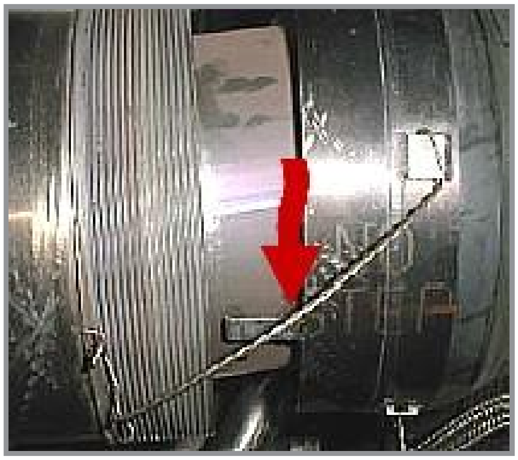
Hard to tell apart

Monel resembles stainless steel but is an alloy of Nickel and Copper. Probably the easiest method of telling stainless steel from Monel is the spark test. Stainless steel will create sparks when placed against a grinding wheel. Monel (and most nickel alloys) are "non-sparking"

Monel wire is used by deep sea fisherman as a trolling, seizing and baiting wire because it can be rolled and bent many times without breaking - unlike stainless wire. And its extra softness makes it easier to use. Monel safety wire was used exclusively on the Titan II rocket engine (picture below is from a Titan II). Given that the operational life was 3 1/2 minutes for this first stage engine one wonders why safety wire was even needed.

Monel Safety Wire used on the Titan Rocket Engine

Monel is used in potentially explosive-atmospheres where the materials must not be capable of sparking. An example is using monel safety wire in an aircraft fuel tank instead of stainless steel safety wire. Reference Boeing-767 AD-2006-08-04. Although, stainless steel has lower potential to spark from friction than a tool steel, Monel is even better.



Long gap between safety wire ends

In the picture above, the long unsupported gap between safety wire ends and engine vibration may cause the wire to resonate and fatigue fail. Monel safety wire, with its better toughness and fatigue strength, is a better choice than standard safety wire in this application. In this picture the stainless steel safety-wire-fatigue-failure caused a forced landing Airbus-A330-301. 1. The V-band clamp unwound when the safety wire broke and this resulted in 600 degree C. hot air to enter the engine compartment setting off the fire detection system.
Ref: AAIU-Synoptic-Report-No-2006-006

Identification:
Nitric-acid turns metal blue-green. Steel rod rubbed in solution will turn copper colored. Non-magnetic - magnet will not stick. Monel is magnetic whereas "K" monel is non magnetic Stainless Steel and Monel safety wire look almost identical. If you take a piece of wire and hold it to a grinding wheel, the stainless steel will spark and the monel won't.

Advantages of Monel:

- Monel is used in high-temperature areas such as on the exhaust. Monel 400 melts at 2,600 degrees F.
- Monel is used for locations where you don't want a spark, such as inside fuel tanks.
- Monel resists breakage when bent or vibrated much better than stainless.
- Monel is an excellent general purpose wire and better then stainless steel as it will bend more without breaking. This make Monel re-usable.
- Monel is also a little bit softer so is easier to work with your hands.

Titanium Limitations in Aircraft Repair

Titanium is entering main-stream usage. The Boeing 787 is 18% by weight titanium. To maintain aircraft that contain titanium it helps to know the material's quirks and limitations...and titanium has a few big ones... such as titanium's fire hazard; Titanium catches fire before it melts - unusual for a metal.

Fire Hazard:
"There have been over 140 known instances of titanium fires in aircraft turbine engines in flight and in ground tests" 1.

Fire damage to titanium and titanium alloys becomes critical above 1000 degrees F due to the absorption of oxygen and nitrogen from the air which causes surface hardening to a point of brittleness. An overtemperatured condition is indicated by the formation of an oxide coating and can be easily detected by a light green to white color. If this indication is apparent following fire damage to titanium aircraft parts, the affected parts will be removed and replaced with serviceable parts. T.O. 1-1A-9 page 5-6

"The application of titanium in the engine design should be directed primarily to minimizing the probability of uncontained titanium fires, i.e., fires that penetrate the engine casing" 1.

1. FAA AC33.4 "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines.

Hydrogen Embrittlement
Hydrogen-embrittlement is a major problem with titanium and titanium alloys. Hydrogen is readily absorbed from pickling, cleaning and scale removal solution at room temperature and from the atmosphere at elevated temperatures. Hydrogen embrittlement in the basically pure and alpha alloys is evident by a reduction in ductility and a slight increase in strength. This is associated with a decrease in impact strength at temperatures below 200 degrees F. and a shift in the temperature range where the change form ductile to brittle occurs.

With alpha-beta alloys, embrittlement is found at slow speeds of testing and under constant or "sustained" loads as demonstrated by tests on notched specimens. This type of embrittlement, which is similar to the embrittlement of steel, only becomes evident above a certain strength level. Solution heat treating and aging the alpha-beta alloys to high strength levels increases sensitivity to hydrogen embrittlement.

Cadmium Plate Caution

Cadmium plated self-locking nuts shall not be used in contact with titanium and titanium alloy bolts, screws, or studs in application where the operating temperature exceed 450 degrees F. Cadmium plated clamps, fixtures, and structures per Aeronautical-Design-Standard-ADS-13F-HDBK. Note, when considering localized cadmium embrittlement of titanium, consider that friction can sometimes cause this heating effect.

Boeing-Design-Manual-BDM-1054 states "The use of cadmium plated titanium components is not allowed. Cadmium plated components which come in contact with titanium are not allowed, except for hydraulic systems where cadmium plated steel fittings may be coupled to titanium fittings and cadmium plated steel or titanium nuts on titanium or steel bolts. MIL-S-5002 prohibits all contact between titanium and cadmium on military programs." Cadmium plated clamps, fixtures, and\ jigs should not be used for the fabrication or assembly of titanium components or structures. Cadmium plated self-locking nuts shall not be used in contact with titanium and titanium alloy bolts, screws or studs. MIL-HDBK-1599A.

Silver Plate Caution

Silver-plated self-locking nuts shall not be used in contact with titanium and titanium alloy bolts, screws, or studs in application where the operating temperatures exceed 600 degrees F. Per MIL-STD-1515A "Fastener Systems for Aerospace Applications" Silver brazing of titanium parts should be avoided for elevated temperature applications." ADS-13F-HDBK at temperatures exceeding 230°C (450°F). The warning on cadmium and silver is most likely because it was found that when cadmium or silver plated fasteners were pressed or smeared into the titanium surface at or near the yield of titanium that embrittlement of the titanium and cracking resulted. This became known as cadmium-embrittlement or Solid-Metal-Embrittlement (SME). Any barrier that prevents direct contact (such as a dry film lubricant) can prevent cadmium embrittlement. In most applications, the likelihood of SME is quite low or non-existant since the cadmium must be smeared into the surface while titanium is in tension well above 50% of its yield strength.

Skydrol Caution

Titanium can be embrittled by accumulations of Skydrol-hydraulic-fluid (BMS3-11) at temperatures above 270 degrees F. Per Boeing-Design-Manual-BDM-1054.

Alcohol Caution

Titanium can be embrittled by methyl alcohol and anhydrous ethyl alcohol at room temperature. Per Boeing Design Manual BDM-1054.

Solder Caution

Titanium can be embrittled by silver, zinc, lead and lead alloys at elevated temperatures. Per Boeing Design Manual BDM-1054.

High Temperature Caution

Titanium should not be used at temperatures above 1050 degrees F 565.6 C) as it has an unusually high attraction for carbon, oxygen, nitrogen, and hydrogen above this temperature. This makes the titanium brittle. Working with titanium requiring the application of heat in excess of 800 degrees F., must be performed in a closely controlled atmosphere. The absorption of small amounts of oxygen or nitrogen makes vast changes in the mechanical properties. In gaseous oxygen, a partial pressure of about 50 psi is sufficient to ignite a fresh titanium surface over the temperature range from -250 degrees F to room temperature or higher.

Salt Caution

Titanium is susceptible to stress-corrosion-cracking by sodium chloride or chloride solutions at elevated temperatures. If you are using titanium parts above 450 degrees F (232.2 C), then use a nonchlorinated
solvent and avoid leaving fingerprints.

"An American turbine engine manufacturer recently published a service letter alerting operators that wrapping stainless steel tube assemblies with a chloride-based material, such as neoprene tubing and fibreglass tape to prevent chafing, has resulted in premature tube failure. A chloride-based material breaks down from the presence of high engine temperatures and attracts moisture, resulting in the formation of salts which are highly corrosive to stainless steel tubes. After a period of time, stress cracking develops resulting in failure of the tubes. Additional investigation along the same lines by a foreign engine manufacturer revealed that titanium is also affected by the chemical reaction between chloride-based materials when operating in temperatures in excess of 150 degrees C (302 degrees F).

A related problem is the use of chloride-based packaging material, such as PVC sheeting (plasticized polyvinyl chloride) as a packaging material. This can result in chloride-based residue being left on the component, possibly leading to the sort of failure described above.

In summary, operators are reminded to follow the engine manufacturer's publications in installing stainless steel engine air, oil and fuel tubes and warned against using chloride-based materials on any stainless steel or titanium components, whether installed on the engine or held in storage. " AAC 1-13 Australian-Government-Civil-Aviation-Authority

Mercury Caution

Under certain conditions when in contact with cadmium, silver, mercury, or their compounds, titanium may become brittle. Refer to MIL-S-5002 and MIL-STD-1568 for restrictions concerning applications with titanium when in contact with these metals or their compounds. Silver will cause cracking in many titanium alloys at temperatures above 650 degrees F.

Liquid Oxygen Caution

The use of titanium in contact with liquid oxygen should be avoided since the presence of a fresh surface, caused by cracking or abrasion, may initiate a violent reaction. Per Boeing Design Manual BDM-1054

Wear and Galling Caution

Titanium-galls very easy. It has been described as a "gummy" metal, strong but soft. Titanium threaded fasteners may require anti-seize. The loss of Sikorsky S-92A ship number CHI91 due to galling of titanium studs is an example of how galling is a serious concern. Conversion coatings, such as Tiodize can be applied to titanium fasteners to prevent galling. For example the Titanium interference fit bolts in the F-14 wings would gall if driven into the hole bare. Tiodize coating is used to prevent such galling. Bare titanium should not be used for components having sliding surfaces. Pined joints subject to rotation, vibration, or repeated loads must be bushed with unplated aluminum-nickel-bronze or CRES bushings.

Crevise Corrosion Caution

Titanium is susceptable to crevise-corrosion in chloride (salt) solutions at elevated temperatures. Different heat treatments and alloys vary. "Care should be taken to ensure that cleaning fluids and other chemicals are not used on titanium assemblies where entrapment can occur. Substances which are known to be contaminants and which can produce stress corrosion cracking at various temperatures include hydrochloric acid, trichlorethylene, carbon tetrachloride, chlorinated cutting oils, all chlorides, freons, and methyl alcohol." ADS-13F-HDBK

Galvanic Corrosion Caution

Titanium is similar to Monel (nickel-copper alloy) and stainless steel and galvanic reactions generally will not occur when coupled with these materials. Less noble materials, such as aluminum, carbon steel, and magnesium alloys may suffer galvanic corrosion when coupled to titanium.

Welding Caution

Titanium welding must be done in an inert atmosphere. Cracked titanium bicycle frames are a good example of how lax attention to welding details results in fatigue cracks years down the road. Here is a write-up from a fatigue failure of a titanium duct on a Lockheed Tristar:

Although welding of commercially pure titanium normally results in a slight local hardness increase, a well executed weld should only produce an increase in the range 10 to 25 HV. The weld at the duct fracture location exhibited a much greater hardness increase (45 HV) and would therefore be expected to have had reduced ductility, impairing the fatigue characteristics of the duct. A difference greater than 30 HV compared with the parent material with an associated loss of ductility can indicate that gas contamination has occurred, leading to weld embrittlement. Gas contamination and embrittlement occurs when the weld pool is not sufficiently shielded from atmospheric gases such as oxygen, nitrogen and hydrogen. The blue/purple tint to the weld area adjacent to the fracture is evidence of elevated temperature oxidation... AAIB Bulletin No: 6/99 Ref: EW/C98/9/5 Category: 1.1

This report seems to imply that a local hardness test close to the weld may be a good test for excessive embrittlement.

When titanium is heated to 500 degrees C. (930F), it absorbs oxygen, hydrogen, nitrogen, and carbon. These atoms enter the titanium and make it brittle. Evidence of titanium weld contamination is readily apparent as a discoloration of the weld surface. This discoloration is caused by oxidation and starts at about 900 degrees F. Heating to temperatures above 1000 degrees F. under oxidizing conditions results in severe surface oxidation and brittleness.

<u>General Welding Principles:</u>

- Not every good welder can weld titanium - requires discipline.
- Cleanliness. You do need to be manic about cleanliness. Solvents must be very fresh and always stored in sealed containers. Purge gasses need to be pure. Avoid rubber or plastic hoses in handling the gasses. The permeability is too high and you will pick up oxygen and moisture. Use Lint-free gloves after cleaning so as to avoid contaminating the surface with perspiration.
- Protect the backside. Wherever the titanium is heated, brittle alpha-case can form.

- The presence of blue or white oxide is an indicator that contamination has occurred.
- A bright silver color (mercury color) is desired.

High quality industrial and aerospace welding of titanium is done in a hermetic welding chamber which maintaines the atmosphere of Argon with less than 20-ppm O2 and 20-ppm moisture.

Hydrogen Migration to Weld at Elevated Temperature Caution
Metallurgical examination of the duct fracture surfaces showed that it had failed due to cracking from multiple origins on the duct inner surface, adjacent to the weld. Hydride formations were present and the metallurgical report concluded that the failure was similar to that described in Boeing Service Bulletin 747-36A2074...This states "At duct operating temperatures of 300 to 350 degrees Fahrenheit, hydrogen in the titanium duct material tends to migrate towards areas of high stress, and then during cooling, hydrides form. These hydrides have an embrittling effect on the duct material and may contribute to crack initiation...Studies indicate that stress relieving the ducts eliminates the residual stress and local stress concentrations which stops the migration of hydrogen to the circumferential welds." Airframe cycles on duct: 14,698. Ref. AAIB EW/A92/6/1 Boeing 747-283B, G-VOYG

Aircraft Engine Bearing Analysis - Reading the Bearings

These bearings are from Lycoming and Continental aircraft piston engines. In no instance is the bearing itself defective. Bearings are victims of abuse and neglect.

Oil Leaks -- It's not the gasket it's the surface

The only reason we use gaskets is because we can't machine a truly flat surface. Bugatti engine blocks were hand scraped to ensure that the surfaces were so flat that gaskets were not required for sealing! Almost true - they were hand scraped but Bugatti engines did leak oil but the point is that surface flatness is #1 when it comes to sealing surfaces.
Check your surfaces for flatness. A customer brought this cover plate into my store to purchase a gasket. I have this habit of placing plates on the counter upside down and pressing on the edges to see if they rock - a quick check for flatness - this one rocked! A new gasket wouldn't work any better on this plate than the old one. Pretty amazing to me that the customer was unaware of this. He is going to have to flatten this plate.
Another check for flatness is to lightly lap the surfaces and inspect the lap contact area. When I had the overhaul shop we used to do a lot of lapping. Had a lapping plate in the engine shop and a flat piece of thick glass as a lapping plate in the accessory shop.

Saturate some 800 wet-or-dry sandpaper with light oil and then swirl the cover plate across the surface a few times - then you look at the cover plate and see if it is distorted. If it is then continue lapping. Another problem with gaskets is too much torque and you crush the gasket. The motivation is to tighten harder if you have a leak. But look at the picture below. More torque on the bolts and you just distort the surfaces more. The correct amount of bolt torque on a gasketed joint is set by the stress needed in the gasket material to effect a seal and sufficient torque to provide equal pressure across the gasket. Tightening should be done in stages to compress the gasket equally.

Lapping Technique: The cover plate is swirled against the glass and paper. The wet sandpaper will stick to the glass so just pick up the plate and place it onto the sandpaper and lightly swirl the plate. You can lift the plate off and look at the surface and see the contact area. This will tell you if the plate is flat or not. At this stage you are just checking for flatness. If the paper is not removing metal from the entire surface then continue -- hold the plate with light but even pressure - do not force the plate onto the paper as you will press harder on one side than the other.

Here is a video - a couple of comments - outside of a flat-plate (lapping plate) the next best surface to lap against is glass. Do not glue the sandpaper down to the surface - what a mess. Light oil will hold it down. wet both sides of the sandpaper. I have never lapped with water - always light oil but I suppose water would also work.

videos on lapping

Preventing Oil Leaks

Two essential tools missing from almost every aircraft repair shop - an arbor press and a lapping plate!

Aircraft Engine Age Deterioration

In Service Condition Inspection of N6937Y, PA23-250

- Compression: Excellent
- Oil Consumption: Good
- Oil Analysis: Clean
- Oil Filter Examination: OK
- Engine Operation: Smooth

Based on above findings aircraft was operated on June 23, 1996. Aircraft crashed during flight killing all aboard.

- Fatigue crack at corrosion pit between cylinder fins
- In flight fire
- Wing separated in flight
- 5 fatalities

Lycoming connecting rod with rust

Overhaul Condition Inspections that WERE NOT DONE but recommended (Factory overhaul inspections after 12 years; engine time-in-service: 21 years):

- Corrosion and Pitting Inspection
- Magnetic Particle Inspection
- Florescent Penetrant Inspection
- Eddy Current Inspection
- Visual Inspection
- Dimensional and run-out inspection
- Wear and surface damage

These more thorough inspections were not performed presumably because In Service Condition Inspections were all that were required (in the opinion of some airplane owners and mechanics) to determine the safety of the engine. Unfortunately, In Service Condition Inspections were not adequate given the age of the engine. "Bad practices that result in no immediate ill effects wind up becoming the norm."

Age related deterioration may result in sudden and catastrophic engine failure as this example illustrates. This accident, and other age-related-failures, may be prevented on high calender time engines by using more thorough Overhaul Condition Inspections that better inspect for corrosion pitting, fatigue cracks, and other deterioration both external and internal.

Links to accidents related to corrosion pitting:

Lycoming fuel injector lines

Crankshaft Failure of antique engine

Navion Crankshaft Failure - pitting on fillet

A 150 μm deep (0.010 inch) corrosion pit

A post-mortem examination found evidence of soot in the airway of the pilot, which *indicated that he had been breathing during exposure to smoke. Toxicology results showed the presence of cyanide in the pilot's blood at a significantly elevated level; cyanide is a common combustion product of some materials found in aircraft construction.*

Cessna 152 Cylinder Failure

Engine Failure/Fire Piston Pin Pitting

Propeller Loss *"Had the failed engine been overhauled within the manufacturer's recommended time of 2000 hours, or even within 2200 hours had it met the manufacturer's 200-hour extension requirements, the overhaul would have occurred before the flange cracking had reached a critical stage and the crankshaft should have been scrapped."*

The occupants were fatally injured. "A fatigue crack developed in the engine crankshaft as a result of corrosion pitting and the absence of a case-hardened layer on the fillet radius of the number six connecting rod journal. The fatigue failure of this section of the engine crankshaft resulted in a complete loss of power."

Both occupants were fatally injured. The helicopter was completely destroyed in the post-impact fire. Enstrom F-28C Helicopter C-GVQQ total time in service of 611 hours over the 27 years since the 1982 overhaul. "The fracture of the check ball retainer in the exhaust valve hydraulic tappet..."

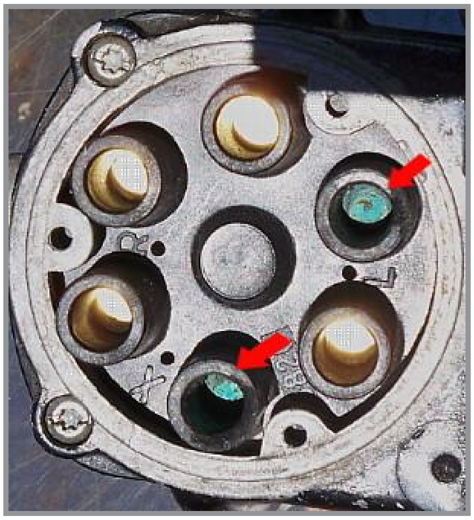
Calender time and Hours (stress cycles) are both considerations for continued safe operation

I0-520 Cylinder with combustion chamber cracks

"Old designs are never proven for fatigue simply by virture of their longevity. Fatigue is wear-out. There is no guarantee that future failures will be confined to those seen in the past." Steve Swift,GNATS AND CAMELS - 30 Years of Regulating Structural Fatigue in Light Aircraft"

Crankshaft Fatigue Failure in TIO-540 Engines operarating past TBO

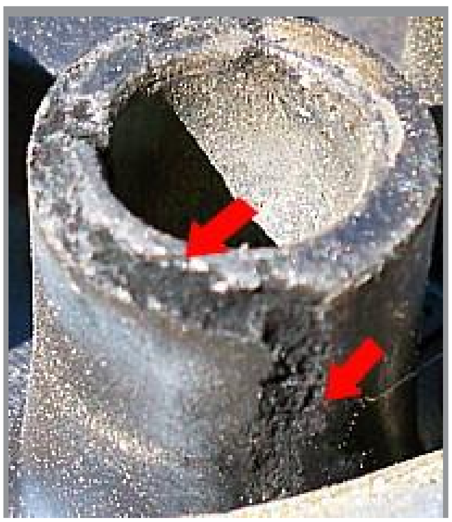
Slick Magneto Inspection Tip



Slick Magneto Arching damage
Engine roughness has many causes. Here is one item to check; quick and easy:

Remove the harness caps and inspect the distributor block. Look for:

- Erosion or burning on towers
- Color differences in lead contact buttons
- Carbon dust



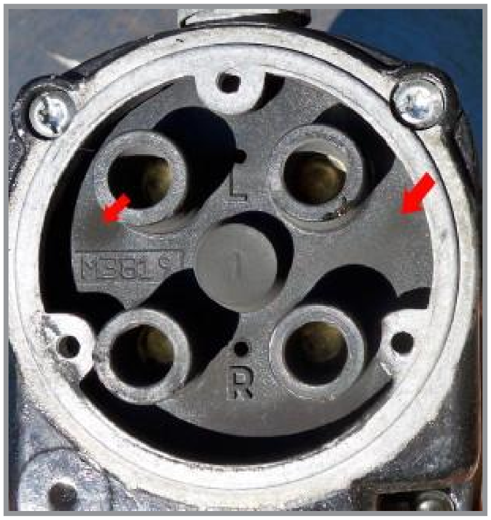
Notice the burning (arching damage) and color change. Lots of erosion; this engine had a miss for a long time. Slick Magneto Arching damage Closeup This damage is caused by the electrical arc bypassing the spark plug and finding an easier ground path along the lead tower and to the magneto housing. The magneto below has a different problem.

Slick Magneto Carbon Dust There is a layer of black carbon dust shown by the red arrows. Carbon dust is conductive and can cause arching to ground inside the magneto instead of at the spark plug. Lets take a look inside this magneto. Slick magneto carbon brush This is the worn carbon brush inside the magneto. Just as we suspected from all of the carbon dust on the distributor cap. Here is what internal arching does to the insides of the magneto. That carbon dust is bad stuff.

Slick magneto arching damage Notice the white residue. You will find this inside the magneto cap. If you remove the harness cover and see white residue on the lead towers then there is lots more inside. In case you're interested; this magneto did run and pass a mag check -- it just crapped out at full power and resulted in an aborted takeoff.

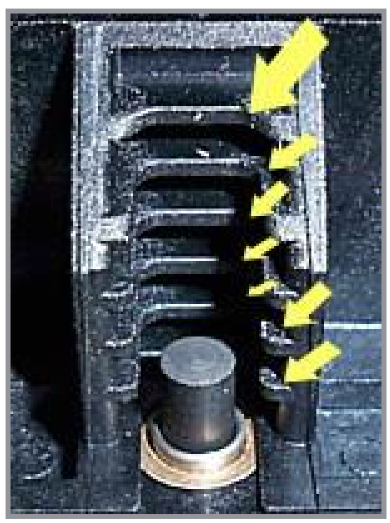
Slick Magneto white residue
There have been improvements in the Slick magneto. The picture below shows the carbon brush and the insulating portion of the distributor block. Notice the "dams" (yellow arrows). They are new as of about 2010.

Slick magneto distributor block closeup showing dams These "dams" serve the same



purpose as the ones below on a electrical transmission tower insulator. You might have also seen these on some spark plugs.
Electrical Tower Insulator Original (old) style
This older style has no dams. The dams capture the dust and provide a longer electrical path to ground.

Removing the harness cap and inspecting the top of the distributor block can be quite revealing and save you troubleshooting time; it can find problems early and at little cost. Of course all of this stuff I write about here is part of Mechanic's Toolbox Software.




Propeller blade cracks

Some interesting stuff on inspecting propeller blades for cracks before flight. Australian Airworthiness Bulletin 61-008 "To provide guidance on propeller continuing airworthiness/maintenance practices"

A few quotes from the bulletin:

detection of the crack may only be possible from the rear of the blade

I always looked at the front - good advise - article has an good explanation as to why. Another quote:

Investigation has shown that cracks have propagated over a long period, which in some cases exceeds thirty ground/air/ground cycles i.e. thirty flights. There is no evidence to suggest that failures have occurred where a crack may have propagated from initiation to final failure in one ground/air/ground cycle i.e. one flight. Therefore detection of the crack and prevention of failures of this nature should be achievable.

A quick inspection before flight can prevent blade failures.

Some blade paint schemes are not conducive to easy inspection of the rear surface of the blade...
This is the big point! A thick durable layer of tough epoxy paint might hide the crack!

Piston engines and engine mounts were painted with a thin coat of brittle enamel paint. Through long experience we found that cracks would appear through the paint. The paint did not prevent inspection. Now the customer wants a thick powder-coat gloss finish. Cracks and corrosion are hidden; inspection is hindered or made impossible. Aerospace is more concerned with performance, endurance, inspectability than cosmetics and bright colors under the hood.

Aircraft Washer Usage

Rule of Flat Washers: All washers shall be made from a material which is capable of accepting the peak fastener load without deformation.

Incorrect washer used on NAS148 high tensile strength bolt led to the loss of N76195 and its occupant A washer can provide multiple functions, the two most important ones are: 1. Spreads the clamping force over a larger area to avoid compressive yielding, and 2. Hard, smooth, consistent material for good preload (clamping) control.

Other functions are to: 1. Prevent galling of the nut face or surface during tightening. 2. Reducing the external load carried by the bolt by increasing the effective pressure area. This stiffens the joint members and the stiffer the joint members the smaller the fraction of external load the bolt will "see". 3. Prevent galvanic corrosion by separating dissimilar metals. Example would be using an aluminum washer under a steel bolt head tightened against an aluminum crankcase. Any galvanic corrosion occurs between the washer and bolt head rather than between the crankcase and bolt head. A washer is cheaper to replace then the crankcase. 4. Increase energy stored in bolt by using a longer bolt. This helps retain clamping force. 5. Adjusting grip length.

Washer Strength:

WASHER compressive strength MUST be matched to the BOLT/NUT combination! Pictured above is a low-yield strength hardware store washer placed under a propeller bolt. Low-yield strength washers that score/crush in-service under high strength BOLT heads or NUTS relieves the clamping force, eventually resulting in propeller detachment during operation.

High-Strength Aircraft Washers MS20002

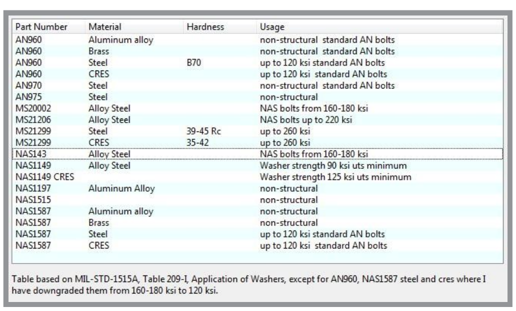
MS20002 smaller inside diameter for closer fit to bolt shank Standard AN960 has larger inside diameter - less bearing surface area A size comparision of the common AN960 washer with the harder MS20002 reveals that the MS20002 washer has a smaller diameter inner hole and a slightly larger outside diameter. The non-chamfered version offers approximately 20% more surface area to the nut. For example, a 1/4 inch AN960 has a surface area of .13989 sq. in. compared to .16998 sq. in. for the MS20002, thereby reducing the stress per square inch on the washer by spreading the load over a larger surface area. This helps prevent washer or faying surface crushing and reduces joint embedment relaxation. A quick calculation shows that when a AN4 bolt is fully torqued the stress per square inch on the washer reduces from 18,000 psi with the AN960 washer to 15,000 psi for the MS20002 washer

Comparing Thickness - high-strength washer next to head is thicker than standard washer

MS20002C - bevel to clear radius at bolt shank to head

Aircraft Washer Usage Chart

When not to use a washer



Part Number	Material	Hardness	Usage
AN960	Aluminum alloy		non-structural standard AN bolts
AN960	Brass		non-structural standard AN bolts
AN960	Steel	B70	up to 120 ksi standard AN bolts
AN960	CRES		up to 120 ksi standard AN bolts
AN970	Steel		non-structural standard AN bolts
AN975	Steel		non-structural
MS20002	Alloy Steel		NAS bolts from 160-180 ksi
MS21206	Alloy Steel		NAS bolts up to 220 ksi
MS21299	Steel	39-45 Rc	up to 260 ksi
MS21299	CRES	35-42	up to 260 ksi
NAS143	Alloy Steel		NAS bolts from 160-180 ksi
NAS1149	Alloy Steel		Washer strength 90 ksi uts minimum
NAS1149 CRES			Washer strength 125 ksi uts minimum
NAS1197	Aluminum Alloy		non-structural
NAS1515			non-structural
NAS1587	Aluminum alloy		non-structural
NAS1587	Brass		non-structural
NAS1587	Steel		up to 120 ksi standard AN bolts
NAS1587	CRES		up to 120 ksi standard AN bolts

Table based on MIL-STD-1515A, Table 209-I, Application of Washers, except for AN960, NAS1587 steel and cres where I have downgraded them from 160-180 ksi to 120 ksi.

Incorrect - no washer needed or desired here When NOT to use a washer. The built-in washer under the head of a flange head bolt acts to distribute the clamping load over a greater area. No washer is needed or desired. This aircraft starter is assembled with washers under the flanged bolt head. Notice that the bolt head overhangs the washer more on the left side. Bolt now has prying tension.

Calculating Surface Pressure:

Not only the washer but the joint (faying) surfaces must have adequate compressive strength.

Crushing - tightening beyond compressive yield strength of bearing material.

To calculate bearing-stress (surface-pressure), you take the bolt-tension and divide by the contact area between the bolt head and the part. You then compare this value to the allowable surface pressure for

the joint material. The allowable contact stress for material is usually about equal to the ultimate tensile strength due to the nature of localized forces on solid bodies.

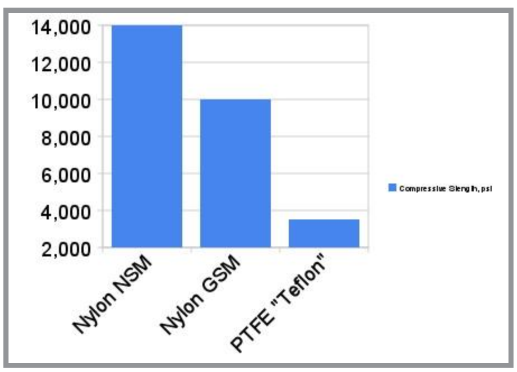
A rule of thumb is that the allowable surface pressure is approximately equal to the material's ultimate tensile-strength (due to elastic and plastic constraint from the surrounding material). Even if you reach the pressure limit, that just means you begin indentation of the part, which does not necessarily mean part failure. You will need to decide what the part limits are with respect to static and cyclic loading, temperature exposure, etc.

Non-Metallic Washers

Aircraft Spinner with non-metallic washer

Some aircraft applications use a non-metallic washer such as under propeller spinner screws. Typically, these washers are made from high compressive strength phenolic or sometimes nylon so that the screw can be tightened without crushing the washer. Some have suggested using a "Teflon" washer.

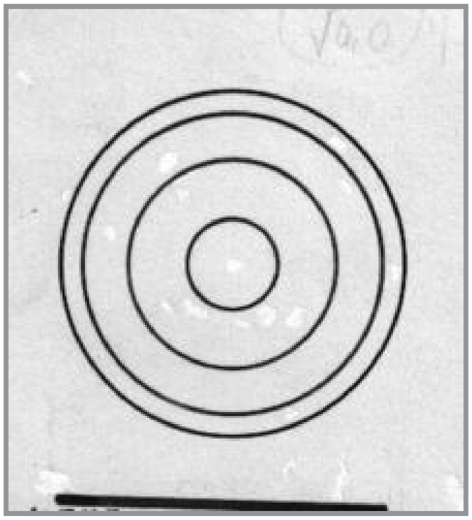
PTFE "Teflon" is has a tendecy to creep under compression (cold flow). In other words "it runs away from the stress" and leaves the screw loose. This low compressive strength can result in loose fasteners and joints when used as a washer under screw heads. To illustate the low compressive strength of PTFE, the chart below compares Nylon's compressive strength to PTFE. Care needs to be exercised when substituting materials that the substitute has suitable mechanical properties to function as well as the original.



Plastic washer material strength

Exhaust Valve Deposits - Concentricity

Look for deposit concentricity. This pattern can only occur if the temperature across the valve face is the same at any distance along the radius. Even temperature can not occur if the valve is leaking hot exhaust at a spot on the circumference.



Concentric

Concentric - deposits share same center axis shows that valve face temperature is the same at any distance from the center. If the valve face were leaking then the temperature at that spot would be hotter and the deposits would no longer be concentric.

Continental Exhaust Valve Concentric Deposits

<u>**Not Concentric**</u>

Not Concentric - valve face leakage

<u>**Not Concentric**</u>

Exhaust valve leakage

<u>**Not Concentric**</u>

Lycoming exhaust valve leakage

High MP low RPM Continental TSIO520 engine (or Lycoming engines)

Hi John. I enjoy and learn a lot reading your monthly mechanic`s tool. Thank you very much.I am a pilot and would like to your point of view from a discussion some of us been having for quite a time: it is there any problem on a turbocharge engine to operate on low rpm and high manifold press. i.e.: cessna 421 at 40" and 1900 rpm for a 5 to 10 minutes period of time?.I would appreciate your comments.

Your joking right? Your not aware of Cape Air/Hyannis Air Services Inc.'s engines slinging pendulum absorbers through the crankcase?

http://www.avweb.com/avwebflash/news/Cape_Air_Grounds_Cessna_402_Fleet_195402-1.html

or, Continental Service Bulletin SS107-5,

Or this from Continental:

SUBJECT: MINIMUM CRUISE RPM LIMITS

PURPOSE: To inform operators of the possible long term effects of low engine RPM in cruise conditions. To establish limitation of minimum engine RPM in cruise.

COMPLIANCE Upon issuance of this bulletin
MODELSAFFECTED: O-470-G; IO-470-N; IO-520-BB, CB, MB, P; IO-550-A, B, C, D, E, F, G, L, M, N, P, R; IOF-550-B, C, D, E, F, L, N, P, R;
TSIO-520-AE, BB, BE, CE, DB, EB, JB, KB, LB, NB, UB, VB, WB; LTSIO-520AE; TSIO-550-A, B, C, E, K; TSIOF-550- J; TSIOL-550-A, B, C
Teledyne Continental Motors (TCM) has examined recent occurrences of crankshaft counterweight release and subsequent engine stoppage in two high time IO-520 and two high time TSIO-520 engine models. Investigation and reported service history lead us to believe that these occurrences are associated with engine operation at sustained cruise engine RPM of less than 2300 RPM. Power settings of less than 2300 RPM have been within the recommended cruise range allowed by TCM's Model Specifications. It is TCM's belief that the population of aircraft equipped with the affected engine models that operate using an RPM less than 2300 RPM for extended cruise operation is limited. TCM will continue to evaluate these reported counterweight releases in an attempt to establish a root cause, including any possible connection with power settings. TCM has not been made aware of any additional confirmed occurrences of this type beyond those mentioned above. Effective immediately, TCM strongly recommends the following limitation be observed on all the models affected above:
Engine cruise RPM settings should be no lower than 2300 RPM.
NOTE … This limitation applies only to cruise operation and is not meant to supersede the aircraft manufacturers' recommendations for other operational modes such as emergency or holding procedures. Any engine listed in the models affected that has been consistently operated outside the recommended limitation in this bulletin should contact TCM Technical Customer Service at 1-888-826-5465 Option 1 or 1-251-438-3411 x8299 for further information and instructions

Pendulum Absorbers mounted on crankshaft

----------------------Here is the problem ----------------------

Counterweights are in fact pendulum absorbers that have a fixed capacity to absorb torsional crankshaft energy. If you feed in more energy than they can absorb they "detune" or "jump" . By detuning, the absorber, which is free to swing like a pendulum, no longer swings but bounces around violently. This violent bouncing will break or knock out the retaining rings and plates and detach the absorber. How do you feed in more energy? - by increasing the torsional twisting of the crankshaft. You do this when you: a. increase engine torque by increasing MP b. operating at an rpm that coincides with the crankshaft's resonant frequency. The resonant frequency is around 2000 rpm for the 520 crankshaft.

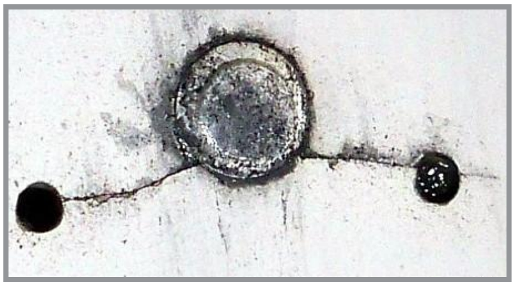
So by operating at low rpm/high mp you are close to peak energy input into the 6th order absorbers. But there is more to this story. When the absorber is far from peak energy it kind of sits there and wears a depression into the bushing (frets). This changes the pendulum length and the absorber's natural frequency. This means that its energy absorbtion capability is reduced. So as you're engine gets to "high-time" or close to tbo in hours, the 6th order counterweights are more sensitive to detuning.

Now about operating for a short period of time? Keep in mind that once the absorber detunes it jumps to a different curve and doesn't come back into tune unless you bring the power back to close to idle. Think of a child on a swing - your absorber is suspended in exactly the same manner (bifler suspension - at two points). The child swings smoothly, but if you disturb the swing it stops swinging and you must grab the child and completely stop the swing and start over.

Crankshaft with pendulum absorber removed. Circlip, Plates and internal pin provide a bifler attachment

Further reading on this subject

Aircraft Rivet Hole Fatigue Strength



Smoking rivet and failed stop-drilled holes One lousy hole out of thousands and the aircraft crashes killing all occupants: "The points where the fatigue fracture originated were in a rough drilled surface where the edge of the drill had left a sharp corner at the change in section thickness near the bottom of the hole." Loss of Helo H-295 August 21, 1971

Every open hole distorts (strains) under loading. Cyclic loading results in repeated loading and unloading of the hole. This is the mechanism for fatigue crack initiation and growth. A tightly installed plug (fastener) in a hole inhibits this strain-deformation.

Burrs increase stress concentration at hole edges. Crack-growth is largely independent of material tensile strength.

Chart from Repairs to Damage Tolerant Aircraft by T. Swift, Federal Aviation Administration, FAA-AIR-90-01.

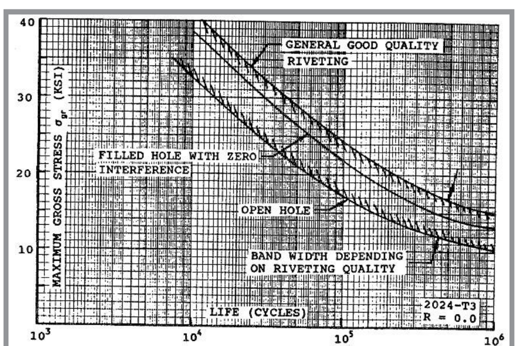


Fig. 24. Effect Of Riveting Quality On Fatigue Life

Proper riveting (filling the hole) increases fatigue life over an unfilled hole. An open hole increases stress by a factor of three times. A filled hole reduces this stress concentration to two times. An interference fit filled hole, for example bucking a rivet into the hole further reduces the stress concentration factor. Per FAA-AIR-90-01 Fig. 20.

Stop-drilled holes should be filled. Also, use proper rivet technique so that the rivet swells and fills the hole. This places the hole boundary in compression. For the rivet to swell and fill the hole the rivet must be driven squarely and not "clinched" When clinching occurs the hole is not properly filled and swelling does not occur. Thus the beneficial residual compressive stresses are not present. When this occurs the fatigue life is no

more than an open hole.

Static Strength Considerations Rivet tear-out
Up till now the discussion concerns cyclic strength. What about static strength? General considerations for the mechanic regarding holes and static strength are as follows:

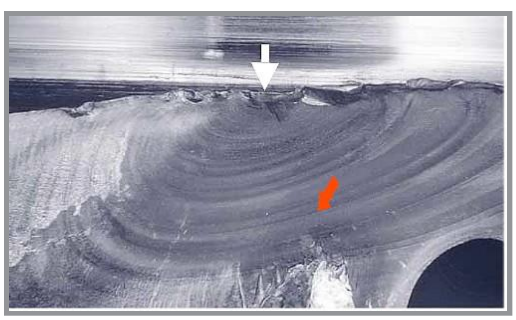
For isotropic materials (materials like an infinite sheet of aluminum that are the same in all directions):
The presence of a hole has little effect on the static fracture strength of a ductile material.
The presence of a hole has a large effect on the static fracture strength of a brittle material.

For non-isotropic materials such as laminated composits:
Fracture strength is a function of hole size "hole size effect" and for multiple holes, hole interaction - in short the subject is complex.

Metal Fatigue, Cracks, and Turbo Mallards

Fatigue Failure with attempted repair

Metal Fatigue occurs when the metal is subjected to repeated or alternating stresses below the material's static yield strength. Fatigue failure occurs BELOW the material's ultimate tensile strength. Parts that are exposed to alternating stress cycles, such as engine crankshafts, may break even though they were never stressed near their ultimate strength. How does one know if a part is close to fatigue failure?



Fractured aircraft engine crankshaft. Beech Marks are a sign that a crack progressed across the part and failure was due to metal fatigue (red arrow). The white arrow shows the crack initiation point.

Fatigue life is determined by the number and magnitude of the stress cycles. Fatigue cannot be inspected -- unless you know the past history of a part, there is no method of determining how many stress cycles and therefore how close to fatigue failure the part is at.

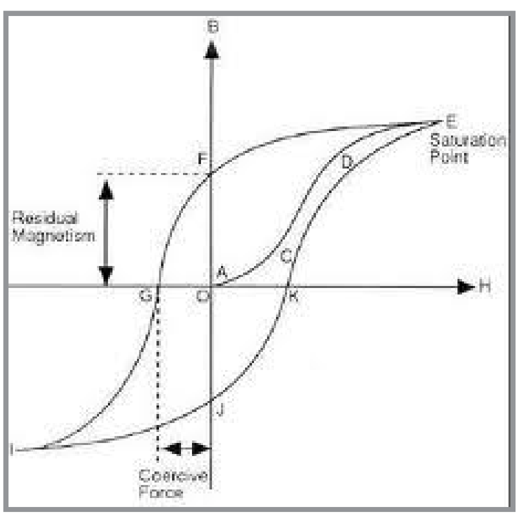
Aircraft components that are described as being "zero timed", "like new", or "restored" are marketing terms that do not describe the remaining fatigue strength. That is the challenge of aging aircraft and purchasing critical stressed components where the past history is not known.

Engineering Critical Assessment: Without knowing the past loading history, the only method of evaluating the failure potential by fatigue is through an engineering critical assessment using Damage Tolerance methods such as fracture toughness, allowable flaw size; and through this process inspecting for existing flaws and calculating the tolerable flaw size for the projected future loading spectrum. What this means to the mechanic is that maintenance cannot prevent fatigue failure, cannot inspect for fatigue failure, nor determine airworthiness from a metal fatigue basis without something to inspect; and without an Engineering Critical Assessment there is nothing to inspect. This is the issue that the mechanics of N2969, the Turbo Mallard who's wing broke off killing all 20 people aboard. An old airplane with skin cracks -- where is the point of failure; it could be the moment a crack is formed, or it could be a defined crack length based on an appropriate fracture mechanics analysis and following applicable codes. It is safe to say that all aircraft have cracks and that not all cracks are a point of failure; in each case what is appropriate--replacement or repair? Without unambiguous maintenance standards based on engineering analysis, fatigue failures will continue regardless of the intensity or quality of maintenance.

"Old designs are never proven for fatigue simply by virture of their longevity. Fatigue is wear-out. There is no guarantee that future failures will be confined to those seen in the past." Steve Swift, GNATS AND CAMELS - 30 Years of Regulating Structural Fatigue in Light Aircraft"

Comet 1 SN Diagram Animation

How to Properly re-magnetize a magneto rotor magnet?



Hi,Just found your sight. Seems like a great resource.I work on aircraft junk we run on airboats. I like to know all the proper procedures and information I can learn. In what book or lesson can I find out how to properly re magnetize a rotor?Your help is appreciated.

Gain a thorough understanding of the Magnetic Hysteresis Curve:

Hysteresis Curve for a Ferromagnetic Material

Allowing the magnet to drop from E to F on the curve is the most common mistake.

Here is a link for a pretty good description of the curve

A link to a more detail description I wrote some years back

Suspect Un-Airworthiness

Letter received from a friend:

The pic is of a freshly topped XYZ engine. We sent it back to XYZ cause we had metal in the filter and because they had fitted the wrong rockers. This engine is on it's third camshaft since last overhaul. Pilot is not happy with the vibration and missing. Pull filter and there are 2 strings of red silastic and metal. As you can see in the pic, they have put silastic between the case and the cylinder base. Suprisingly they have had a rash of through bolt and stud failures. Can't imagine why. They just don't see a problem. You'll love this; they rang and said that at oil change time should be pretty normal to find a match head of metal in the filter, comes from the cam and wear on the cylinder walls. I'm now the baddy in this. If I let it fly and the engine packs up over rough country, I'm in the gun. If I dig my toes in, will they strip it and admit it has something wrong.

So what do you do when you discover serious problems with an engine and the manufacturer's service rep tells you "it's normal" don't worry? "Put it in writing" is my immediate response but beyond that how do you approach the problem? Here is my suggestion.

You can go round-and-round on what is "normal" and what is "airworthy" with manufacturer's and repair agencies but this misses the point. They all work to an approved process that is kept in check by their quality control system. Deviations to the approved process that escape the quality system are evidence of a process deviation and a quality system break-down. Product released during the time of deviation is an escape and is not approved nor airworthy because it does not, or is suspect, as being not in conformance. Part of the definition of "Airworthy" is that the *the part conforms to its type design." Airworthiness is not the determination by the companie's service rep that unapproved material in the oil system is normal.*

The exact nature of the non-conformance i.e. silastic or bits of metal, is not the issue. The issue is that the engine escaped their quality system, has suspect deviation from their quality process and is therefore "not airworthy" The product can only be re-inspected and made airworthy after the process and QC system is brought back into compliance as evidenced by corrective action and audit to confirm that the "corrective actions" are successful.

It appears that there is a break-down in their quality control system. I would not accept repairs as "approved" or "airworthy" during the time of non-conformance. Can they provide the date of the last quality audit and what corrective actions have been made? I would be concerned that your response was an individual opinion and does not reflect the requirements of their quality system.

Put your concerns in writing. Send it to XYZ with a copy to the owner and whatever you call your "FAA". Any decision is outside of your area of expertise -- you can only express a "concern" Let engineering "XYZ" and standards "FAA" make the decision.

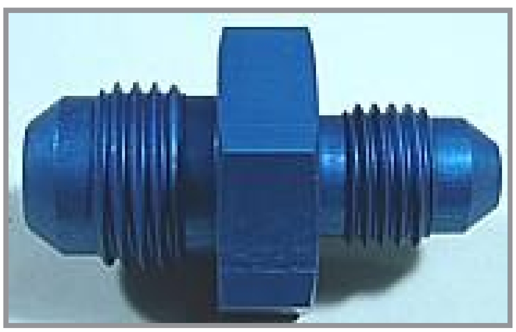
I have seen a Lycoming failure caused by a "match head' size of Silastic that entered the oil system and stuck at the rod bearing oil port where it starved the rod bearing of oil. My recommendation based on experience is to fully inspect all oil passageways for unapproved material.

Normal wear does not occur as metal chunks.
Parting sealant "Silastic" loose in the engine indicates that gasket material has extruded from between the parting surfaces causing cylinder-to-crankcase embedment relaxation. I doubt joint loosening caused by gasket extrusion meets design intent.

----------Another potential action you might take if circumstances apply------------

Since you must determine if the item is airworthy *(Airworthy. To determine that the installation of a part complies with the applicable regulations, the installer of the part is ultimately responsible for establishing that the part conforms to its type design and is in a condition for safe operation.).* AND you suspect that it might not be then (at least in the US) you can file a SUP if the company is a PAH Production Approval Holder. A Suspected Unapproved Part (SUP) is "new parts that have passed through a PAH's quality system which do not conform to the approved design/data." AC No: 21-29C Change 1, Definitions p. Unapproved Part(2)

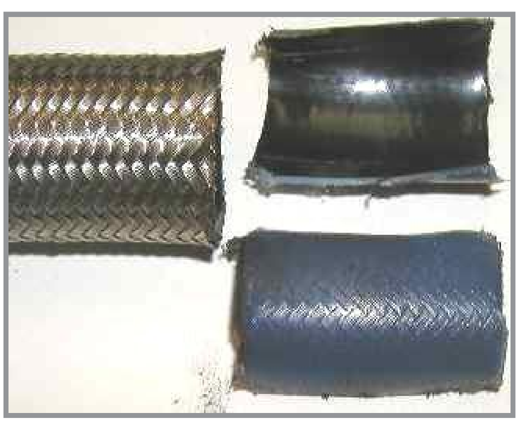
Aircraft Hose Bonding and Lightening Protection



Lessons from Agusta Bell 206B JetRanger II, G-AWMK

AN919 anodized aluminum fitting is an insulator
Current commercial and military-aircraft standard for electrical bonding: 0.0025 ohm for lightening protection and RF potentials.

Unlike other electrical systems, aircraft systems use the structure (skin and/or airframe) as a current-carrying-conductor. There is no "neutral" wire in aircraft. The aircraft skin and components (and hoses) carry the return current back to the battery.



Aircraft can develop high static electrical charges as is evidenced by the need for static-dischargers. Arching can occur between aircraft parts that are at different electrical potentials. In some aircraft, hose is routed through the fuel-tanks. Arching within the fuel tanks can occur if a bonded hose is within spark distance of an unbonded hose (Augusta Bell 206B had an in-flight fuel-tank-explosion).

Aircraft can be hit by lightening. Bonded components help the lightening current to flow through the airframe without arching. A bonded component is where a electrical conductive path exists between two aircraft parts. A common example is the installation of a bonding-strap between the engine mount and the airframe. A metal braid fuel hose or metal tube that is not bonded may have the potential to create arching or sparking during a lightening strike.

Most aluminum fittings have an insulation layer on their outer surface that prevents electrical bonding. This insulation layer is called "anodizing". Anodizing colors the aluminum (as the picture to the left shows) and protects it from corrosion. But, it is also an insulator. Removing and installing the hose or tube several times will wear through the insulation on the threads and sealing surfaces.

Aircraft Hose Assembly with anodized aluminum fittings. Anodized aluminum is an insulator.

In the case of the Bell 206B fue- tank-explosion, the hose was not bonded because of the anodized coating and this led to a static discharge between the unbonded hose and a nearby bonded hose. If your application requires bonding, then be careful with anodized aluminum aircraft parts. They are insulators.

Aircraft Teflon hoses (those meeting mil-specifications) have a conductive layer of carbon black to provide provide electrical conductivity and prevent static charges. Commercial (non-aerospace) hose does not have this static control.

Aircraft Teflon hose assembly showing carbon black inner-liner

Military Specification MIL-H-25579E requires that hoses (through -8) be capable of conducting a direct current equal to or greater than 6 microamperes with a test potential of 1,000 volts dc between the hose inner liner and one end fitting. This prevents the build-up of static charge and arc pin hole leaks to the wire braid.

When teflon hose was first used on aircraft it developed pin-hole leaks. The plastic Teflon develops a static charge so great that it arcs to the grounded steel braid causing a small hole in the Teflon.

--story time--

The classic example of bonding is the pilot who complained that every time he started his airplane the mixture control knob got warm. It turns out that his engine mount wasn't grounded to the airframe. The only conductive path for the battery current was back through the mixture control cable. I have also seen this happen with a metal braid oil pressure hose going from the engine to the gauge. All the starter current flowed through the hose braid. The braid lit up like a heater element and cooked the hose. Fortunately it was oil-pressure and not fuel-pressure.

Take a look at that fat #2 or #4 battery cable going to the starter. All of the current flowing from the battery to the starter must also flow back to the battery. It does this through the airframe. The current will take the path of least resistance. Good electrical bonds help deliver current to the starter for quick starts. They also help to keep the current out of your instruments and hoses where it doesn't belong.

The Aircraft Structural Mechanic (why you deserve a pay raise)

"you spend too much time lookin" was the latest comment from the boss; a reflection of a time long gone when aircraft mechanics were first fixit men, and then parts changers. Aircraft Mechanic's lookin is what keeps the airlines flying; it's how transport class airplanes are designed; it's designed into the structure; easy access for lookin, lookin tools, lookin techniques, and methods. Does the organization understand this? If not -- and the aircraft is designed to be damage tolerant --it's not tolerant but a time bomb.

It is expected that the structure overtime will develop damage but that it will be found by the lookin mechanic before it becomes fatal. Damage tolerant structures must have a "high probability of detection" The organization needs to provide the personal, tools, environment to make this possible.

Large aircraft are designed to be damage tolerant 1. -- there is no limit to service life. Aircraft are kept in service by a partnership between the structural designer and the structural mechanic. This is no "remove-and-replace" maintenance; "structural maintenance is the cornerstone for ensuring continued airworthiness of damage tolerant structures." 2.

Damage tolerant allows for cracks in Structurally Significant Items (SSI); it requires timely inspections to detect such damage with a high probability BEFORE residual structural strength falls below specified values. There are no "standard" repairs or inspections. Each inspection and repair to a SSI is designed by the structural engineer, communicated to the structural mechanic without ambiguity, and performed as the engineer designed. When this does not happen, all hell breaks lose and you get Japan 123 type accidents.

"Inspectability" Where and When to Inspect is a key element

Damage tolerant only works when you know where and when to inspect. Fatigue cracking is cumulative with respect to aircraft usage so it is a straight-forward process to monitor. What is not so easy to predict is corrosion damage; both from standard corrosion and stress corrosion. Stress corrosion reduces fatigue life. A damage tolerant structure must include a Comprehensive Corrosion Prevention Program(s). If this program is deficient then fatigue life estimates are not accurate and the whole concept of damage tolerance goes out the window and leaves the structure weaker than anticipated. (Aloha Airlines 243 for example) Corrosion prevention, detection, and removal is required for a damage tolerant structure and the execution of this program is part of the Structural Mechanic's job.

This is the concept and it has worked well. To give an example of just how well: Boeing's 737 had a minimum service design objective of 75,000 flights but high-time aircraft have achieved 90,000 flights. Exceeding the design objective occurs across the Boeing fleet including the 707, 720, 727, 737, 747. 2., 3.

This is not only a Boeing accomplishment but also reflects the performance of the aircraft structural mechanic in meeting the engineering expectations in regards to inspecting, detecting, and repairing. If the organization don't have good lookers then they shouldn't be flying damage tolerant aircraft. You can't attract and keep the best and most responsible aircraft mechanics unless you provide the best wages, benefits, and working conditions.

1.In 1978, the FAA adopted “damage tolerance” as the preferred choice for managing fatigue in civil airliners.
2. Fatigue Issues in Aircraft Maintenance and Repairs, Ulf G. Goranson, Boeing Commercial Airplane Group.
3. Damage Tolerant works only for defects that are detectable. Adhesive bonded structures may have structurally significant defects that are not detectable.

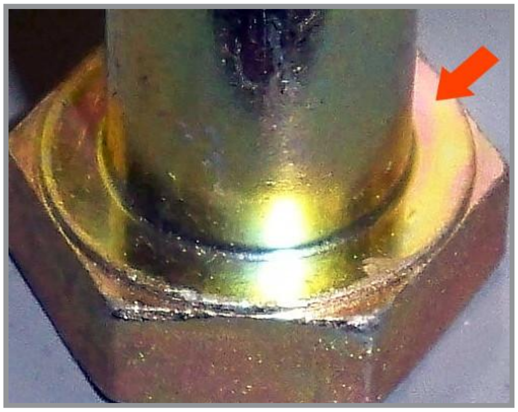
B-nut Torque and Loosening

"Failure of maintenance personnel to properly tighten the fuel supply hose at the engine-driven fuel pump."
Injuries: 3 Fatal.
NTSB Identification: ***ERA09FA068***

It's long been recognized in engineering and among the common man that properly tightened threaded fasteners can become loose. There is an entire industry devoted to making devices that prevent properly tightened threaded fasteners from working loose; lock nuts, lock washers, adhesives of many types, special thread forms.Yet, none of these devices are used on aircraft B-nut connections. (A few aircraft did use lockwire drilled B-nuts, but these are seldom seen).
A survey of aircraft accidents where the B-nut was found loose reveals a bias among accident investigators. Investigators are not investigating why B-nuts may be loose because their bias tells them they already know why; the mechanic didn't tighten it properly. This sloppy and unprofessional work degrades the entire process of accident investigation. Any non-retained threaded fastener can work loose. It is not acceptable to assume that any loose threaded fastener was caused by " improper torque" by the installer without doing some additional inspection work. There are many reasons why a B-nut can work itself loose: thermal expansion and contraction of the joint, vibration, malformed seating surfaces, etc.
A pilot or mechanic or engineer who fails to learn and repeats a mistake can be the probable cause of a future accident; an accident investigator can also be the probable cause of an accident as he had it in his power to prevent it but did not.

AN Bolt Head Design

Dear Sir/Madam, Some 12 months ago I was asked, 'what is the reason for the machined section under the head of some bolts' ?. This I should have know as a licensed aircraft maintenance engineer for more than 40 years, yet the question took me by surprise because I never had cause to question the problem. Today I'm in my 94th year and all of my working life has been in the Automobile and Aircraft fields, of course the Department of Civil Aviation (now CASA) has tested all engineers involved that they know much about bolts, and in particular AN bolts (Air Force/Navy). We must know of metalurgy,



tensile strengths (UTS), yield points, cadmium plating, and the dangers of chrome-plating bolts the requred knowledge seems endless to the stage where BOLTS as such is a complex science, and this leads me to writing this message. In all my years working with bolts I would question most of them, especially in aircraft-but in all those years I never asked why many bolts today have a slightly raised circular section under the head of the bolt within that part of the imagined circle within the under side of the hexagon flats. The raised machine section is only a few thousandths of an inch proud, in the order varying about : 004" to :008" in the ones I've measured. To answer the question I said I didn't know! adding that I had never been asked, nor had queried the reason for the raised section, further adding that I'd find out! With the lack of better knowledge, I suggested to the question that the raised/proud section might be to ensure the first 'bite' in tensioning a bolt fastener is centered immediately close to the bolt shank and that increased tensioning would gradually spread outward from the bolt shank thus ensuring that the initial axial loading would essentially take place radially over the raised portion of the under-head hex, with or without a washer. To me it makes a lot of sense to have this section machined thus preventing sharp edges from the hex edges gouging into the clamped pieces, yet of this I'm unsure.

AN bolt showing washer face

This area is called a "washer face" and defines the bearing area for the bolt head. The bearing area is useful for calculating bearing loads on the washer and/or faying surface so you do not exceed the material's yield strength (crush the joint or washer). It also provides a flat machined bearing surface.

Crushed washer from tightening beyond material's yield strength Washers resting on washer face

I would guess that it is easier to achieve a specified bearing area by machining a circle than by beveling the edges of the hex nut. Another alternative is this:
Here is a link to an article I wrote a while back that touches on the subject of washer unimpressive strength.

Companion article link: AN Nut Head Design

AN Nut Face Design

AN315 nut showing washer face

The previous article I discussed the purpose of the washer face on the bolt head. AN nuts may also (optional for most nuts) use a washer face. It seems obvious that the seating face should be flat, smooth, and perpendicular (within 2 degrees) to the bolt axis.

So how is this design feature of importance to the mechanic? A lot rides on the integrety of this surface:

Face surface influences the tightening tension produced by your torque wrench by controlling friction. It's estimated that 50% of the friction produced during tightening comes from the bolt head and nut surfaces rather than at the threads.

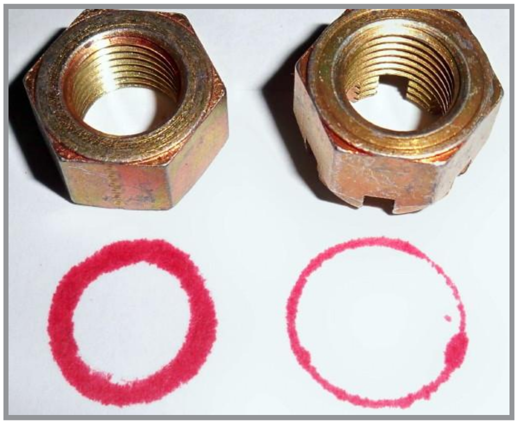
Nut face angularity influences the fatigue life of the bolt. Angularity or lack of, dramatically reduces the bolt's fatigue life. Bolt Science shows that at 2% angularity (at the edge of allowed limit for a common AN nut) can reduce the bolt's fatigue life from 180,000 fatigue cycles to just 10,000 fatigue cycles!

Nut face surface influences how much embedment relaxation (joint loosening) occurs after you stop torquing the joint. The surfaces squish together slightly resulting in a loss of joint tension. An example of this is the crushed washer below. As the washer surface compresses, the joint becomes loose even though it was properly torqued to begin with. Now take a look at the nuts below. The malformed washer faces can crush just like the washer and result in a loose joint.

AN310 Castle Nut with malformed washer face

Compare the contact area of a normal washer face on the left with this malformed washer face on the right. The malformed face concentrates the tension onto a small ring which is more likely going to gouge and crush into the contact surface.

Contact face comparison



Deep ridges on the washer face caused by a dull cutting tool

The malformed nuts shown here reduce the joint integrity which may lead to joint failure, which in the aircraft industry is often catastrophic. As I have observed over the years, if the joint fails due to loosening, it will be assumed without any further investigation that the mechanic didn't tighten the joint properly. example, YOU will be blamed. A quick inspection of surfaces: bolt, nut, faying, washers, is recommended before assembly.

and while I am giving recommendations, torque specifications that specify the application of lubricant are defective if they do not also include where to apply the lubricant. Since the seating surfaces represents 50% of the friction during tightening, it's important to know if the engineer intended that these surfaces, and the thread surfaces, be lubricated. The practice varies among engineer's so there is know way of knowing if the specification doesn't state.

Companion article link AN Bolt Head Design

Unsafe Engineering - Use of NPT Ports in Critical Aircraft Systems

Axial Crack in NPT Port - Aircraft Fuel Pump

"Extreme care shall be taken when tightening pipe fittings. Overtightening causes distortion, cracking, and leaks." Dept. of Army TM-1-1500-204-23-2 Technical Manual, Aviation Maintenance

NPT Advantages:

- Cheap

NPT Disadvantages:

- Cracked Ports
- Leaking Connections
- Not Suitable for Make-and-Break Applications

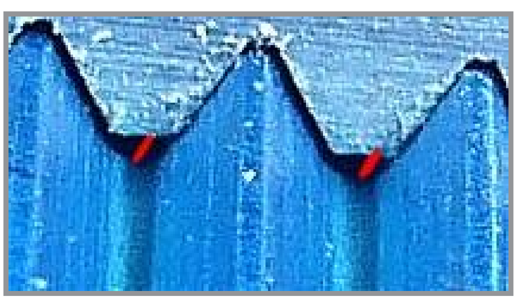
- System contamination due to requirement to use "pipe dope"
- Inadequate or incorrect tightening process in maintenance manuals
- Difficult to specify a tightening process (operator feel is sometimes required, especially on make-and-break connections that have seen multiple assemblies).
- FAA's improper insistence on using a torque value for tightening rather than the design method included in the NPT specification.

I'll throw another one into the pile - poor quality threads. Even in the AN series of fittings the threads quality varies to the point that many will not pass inspection. The responsibility for NPT connection failure should rest on the shoulders of engineering for specifying such an inferior system rather than the mechanic trying to make it work. "Lipstick on a Pig" When a NPT failure occurs on a critical aircraft system, the first question that should be asked is why was NPT specified?

Pipe Dope Contamination of Aircraft Fuel System

The real problem goes back to engineering, best stated by the United Kingdom Air Accidents Investigative Branch: "The use of any kind of jointing compound at any fuel line connection is fundementally unwise." SAFETY RECOMMENDATION - 2004-010 www.aaib.gov.uk.

Pipe Tape Contamination of Aircraft Instrument System



NPT Spiral Leak Path *Leakage path through threads shown at red points. No matter how tight you make NPT threads, a leakage path still exists. It is the function of the jointing compound to block the path between the crest of the male and female thread.*

The use of NPT on thin walled ports is particularly evil as the risk of failure rises:

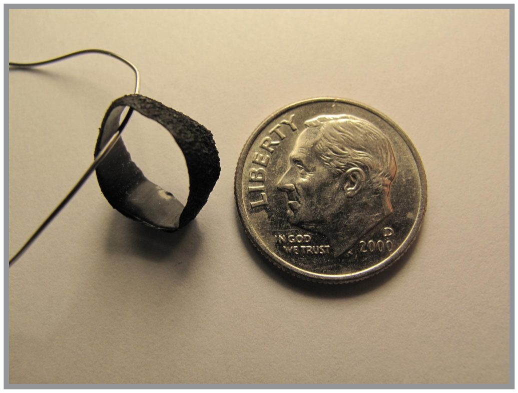
1. Thin wall ports are weaker and are easier to crack.
2. Thin wall ports strain more (expand from tightening) than thicker walled ports. This expansion reduces the amount of tightening torque required. Weaker port + less tightening force felt = higher risk of failure

At least the engineer can specify NPTF for better safety (quality control) -- but this is seldom done! Better yet is a straight threaded port.

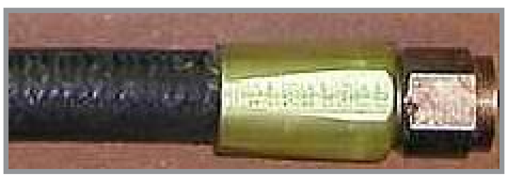
Hose Flap

Hose Flap Hose Flap from MIL-DTL-8794 hose

Stratoflex 111 or Aeroquip 303 Hose Assembly I wrote an article a while back called "The Battle of the Bulge" that goes into some detail on how flaps are prevented, inspected for, and created. Here I want to go into some detail on how to inspect a hose assembly to detect a flap.



For straight hose assemblies you sight through the hose. Be sure to look into both ends, not just one end. The reason you need to look through both ends is that when you are sighting through the hose assembly you are looking for a flap at the far fitting. A small flap at the near fitting might be missed. Also, sighting through both ends is somewhat like taking a "second" look. Also, use a plug gauge like the one shown here.
 Hose Plug Gauge for MIL-DTL-8794 Hose
For hoses with angle fittings where you cannot sight through the hose or use a plug gauge, you drop a ball through the hose. The ball is sized to be just a little bit smaller than the hose fitting inside diameter. For example, a dash 8 111 style hose assembly with 90 degree fittings takes a ball diameter of 0.320 inch. Caution: ball size changes for each type, size, and fitting style hose.



The third method of inspecting for flaps is to flow the hose and inspect how the stream of fluid leaves the hose. This is done during cleaning and as preparation for pressure testing the hose assembly. Typically, a TSO hose shop will use all three methods as part of their quality control system.

Minimum Diameter at the bulge When Hose is Assembled with Adapters per MIL-H-8794D (obsolete)

-3 .080
-4 .132
-5 .200
-6 .260
-8 .350
-10 .450
-12 .575
.

Pilot Description of Preignition

- Then about 30 mins into a flight at about 70% power;
- the # 3 CHT, which had been running at similar levels to the other cylinders at around 180C (say 360F);
- rose to over 250C (say 480F) over a period of less than 5 minutes;
- the engine ran smoothly throughout

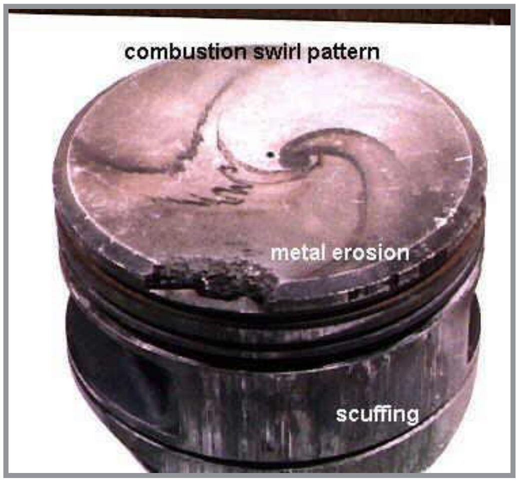
What's starting to happen inside the engine:
Rapid rise in piston temperature = piston thermal expansion resulting in piston scuffing in cylinder bore.

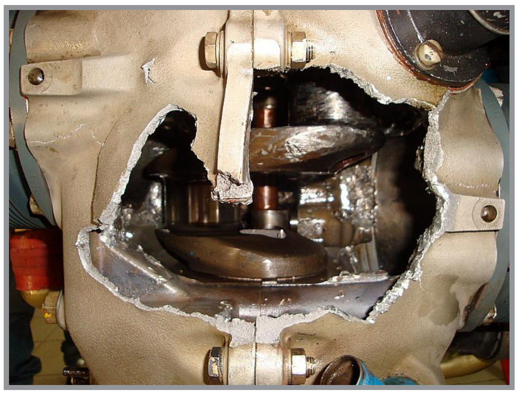
Piston Scuffing Closeup of scuffing:
Piston Scuffing - closeup
Do you know how to shut-down the pregnition? The pilot has 1-5 minutes to shut down the preignition until the following happens. Detonation.

Detonation scoures the protective layer of insulating air that separates the hot gasses from the aluminum piston surface. Remember EGT can be 1,600 degrees F. and aluminum melts at 1,200 degrees F.

Piston starts melting:
Detonation - notice melting at edge of circumference
Another:
Detonation Damage
CHT on one cylinder goes to red line; the engine ran smoothly throughout; less than 5 minutes. Think about this -- would you notice this? Not if you didn't have a CHT probe for each cylinder; not likely if you were busy flying; Luckily, in our description above, the pilot noticed the rapid rise in CHT and reduced power. Unfortunately, he did not know what was happening inside his engine to prevent it from happening again and want back for a second helping.

I have seen the engine monitor graphs of preignition and they are scary -- everything is normal and then out of the blue one cylinder head temperature heads up at a 45 degree angle on the chart. From 300 to 450 in 1-2 minutes from the charts I've seen.





Once the hole is breached in the piston then combustion gas blows into the crankcase and this blows the oil out the breather. You can't stop it from happening without shutting down the engine. Once the oil is blown overboard then this happens. The connecting rod bearing starves of oil and it breaks off; usually by flinging itself through the crankcase.

Moral of this story:

Preignition is dangerous, scary and something that you as a pilot should avoid at all costs. So how do you avoid preignition.

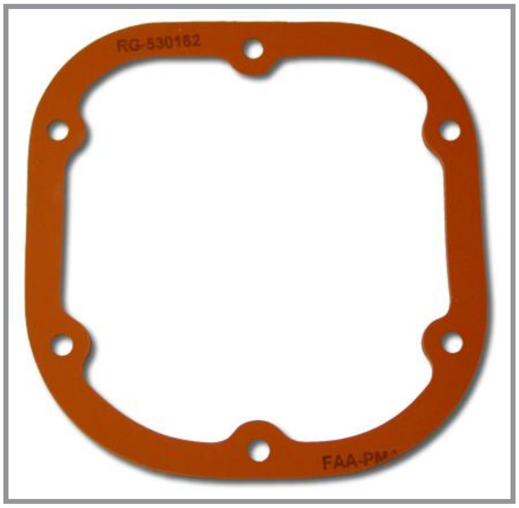
- Understand the heat range of spark plugs and use the appropriate one in your engine based on the maintenance manual AND on how you operate your engine
- Keep magnetos properly timed and maintained
- Operate within the ENGINE MANUFACTURER'S operating envelope. Do you even know where to find this?
- If the engine manufacturer's operating envelope does not allow lean of peak then don't go there.

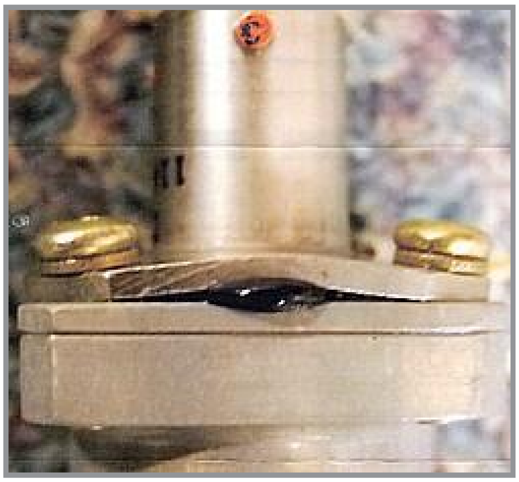
Simple isn't it. Just maintain and operate according to how the engineers designed your engine.

Tightening Rubber Gaskets

I had an interesting conversation with a customer who was replacing a silicone rubber rocker cover gasket on his Lycoming engine. He mentioned that at every inspection he tightens the rocker cover screws slightly. Knowing that the first rule of tightening gaskets is:
1. Do not over tighten. RG-530162 Real Gasket I looked at his old gasket he had brought in and noticed that it had split at the screw holes and had been crushed and distorted.

When one tighens the fastener against a gasket the objective is to "tighten" the joint to prevent leakage. This tightening occurs because the gasket material and joint faying





O-Ring Extrusion

surfaces pushes back against the fastener.
Rubber gaskets behave differently, rubber does not compress, rather it moves away from stress; it changes shape (extrudes) into any free surface. Extra tighening does not tighen. It just increasingly distorts the gasket.
Technically, rubber has a poisson's (pronounced "pwa-son") ratio close to the upper limit of 0.5 meaning that it is incompressible. Now compare this with the traditional cork gasket used on Lycoming rocker cover gaskets; cork has a poisson's ratio close to 0.0. This is why it makes a good cork - when you push on it, it doesn't bulge and can still be pushed back into the wine bottle. Rubber bottle corks are always tapered to allow for bulging.
Cork take-as-set and crush over time which loosens the joint causing leakage. Go back and re-establish proper torque on a cork gasket because they take-a-set and a little extra tightening generally doesn't harm them; and, it is ok to re-establish proper torque on a rubber style gasket but beware that extra tightening doesn't tighten, it distorts.
What about those hybrid gaskets like Continental's rocker cover gaskets? Follow rule #1 Do not over tighten.

Rapidly and Ruthlessly eliminating "customers"

Something a little different today--business advise.

I always keep a $5.00 bill in my wallet. A $5 has the picture of Lincoln and as we know Lincoln freed the slaves. My $5 serves to remind me to always charged for my professional services -- that's what puts food on my table. Only slaves work without getting paid. If I make a mistake, then of course I take care of it to the best of my ability (not God's ability). I have always tried to provide excellent value and not charge for stuff that I didn't earn; but at the end of the day I'm in it for the money as that is what pays the bills.

In response to an email about trying to please a difficult customer, doing free labor as a "favor" to satisfy that difficult customer and being burned in the process...

I've been in your position before and it is uncomfortable and costly. In this industry one has to exercise care in deciding what airplane and which customers you can adequately service and which ones you cannot. I rapidly and ruthlessly eliminate "customers" that are not profitable to my business. Such a policy has not only proved profitable but also lowers my stress levels. I highly recommend it.

30+ years of running a successful aviation business -- paying every bill on time and never late with a payroll

Pilot Description of Broken Impulse Coupling Spring

"Aircraft has a 600 rpm drop on left magneto during run-up. Otherwise engine operates smoothly."

10-52949 Impulse Coupling Spring
Diagnosis: Retarded engine timing caused by broken impulse coupling spring.
Underlying Condition leading to Failure: Corrosion pitting
Prevention: Replace impulse coupling spring on engines that show signs of exterior corrosion and at a maximum of 500 hour intervals or in accordance with manufacturer's recommendations.

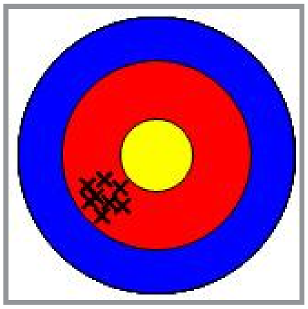
Red rust caused by condensation collecting in magneto. Additional Warnings: D-2000 and D-3000 magnetos, broken impulse coupling can lead to severe loss of engine power and forced landing. Replace spring at each annual inspection might be something to consider.

Additional Instructions:
Here are two videos I did that shows you how to wind impulse coupling springs

Bendix S20/S200 Magnetos

Slick Magnetos

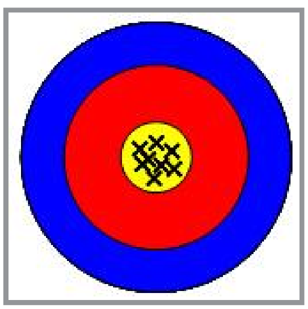
Torque Wrench - Accuracy and Precision



Accuracy and Precision are terms that have very different meanings in the measurement industry whereas in common language there are often used interchangeably with the same meaning. This leads to confusion. Accuracy describes the average whereas precision describes the standard deviation of the average. Precision is often contained by the tolerance. Tolerance is used to define the allowable deviation from average (the amount of acceptable variance, or precision). Confused? An example might help.

To be precise is to hit the same spot every time. Notice on the target the shooter is precise but not accurate.
Now look at the next target. The shooter is accurate (when you average the numbers) but not precise.
The next target is both precise and accurate. Precise is repeatability and accurate hits the spot.

These examples show that we need to know both: accuracy and precision. One or the other gives us little useful information.



This has special meaning for torque wrenches. When the gears wear in a snap style torque wrench the precision gets awful. Lets say we are calibrating your torque wrench and set it to 40 lb-ft. We will click it 10 times and average the 10 readings to arrive at the number we put on your calibration report we send back with the wrench. The first pull and your wrench clicks at 50, next click at 30 and so on until we reach our 10 pulls. We average the values and it comes out to 40. Perfect accuracy!

Your wrench may never have clicked at 40. When you use this wrench you think --aww it's perfectly accurate at 40 which means that if it clicks at 40 it is at 40. But you are wrong because your wrench is not precise. When you use the wrench you are not averaging over 10 pulls -- you get what you get-- so you want your wrench to click at the same value each time (precise) and you want it to click at the correct value(accurate).

So now you know that your torque wrench that advertises itself as accurate to within 5% really means: "On the average I click to within 5% of the set point; however, any one discrete click may occur at any value." Rather worthless information isn't it.

But if the wrench manufacturer also states that are statistically certain that 95% of the time the wrench clicks to within 1 lb-ft. of the set point, then we are more confident that when we use the wrench we will establish the amount of tightening to within the manufacturer's torque tolerance.

To be a little more precise in my writing, calibration shops now use the term uncertainty rather than certainty to define the degree of statistic confidence they have in their reported value. Any modern calibration statement must include an uncertainty value.

Nature of Efficient Design

"designs will fail if subjected to overload...that's just the nature of efficient design"

Broken crankshaft at the fillet

Designs may not fail immediately; this is the trap that entices in the consumer--the desire for more power, greater performance than designed. A popular performance modification.

It's delayed failure due to metal fatigue that kills. A seemingly successful patch, a popular engine modification, an antique airplane used for aerobatics, antique air tankers:

- Aloha Airlines Flight 243
- Japan Flight 123 520 people killed
- N2969 Turbo Mallard Wing Breaking Off
- China Airlines Flight CI-611 225 people killed.

A flight-proven repair, a proven design, long years of successful service were all present in the accidents listed above. Recently I received an inquiry from someone who was surprised that his crankshaft had broken. In talking to him he proudly listed all of his "performance" upgrades that had been done on his engine. Why was he surprised that his crankshaft broke? The only way it would NOT break is if the engineer who designed the crankshaft was inefficient in his design.

Food for thought: Engine horsepower output over time can be no greater than crankshaft fillet fatigue strength.

Cracks in Aircraft Structures

A crack is the first sign of impending failure

Crack in aircraft fuselage

We all know what a crack is when we see one. So what do we do about it? This guide attempts to establish a framework of knowledge about how cracks are viewed in the aircraft industry.

Cylinder barrel crack -aircraft piston cylinder **1. The Definition**

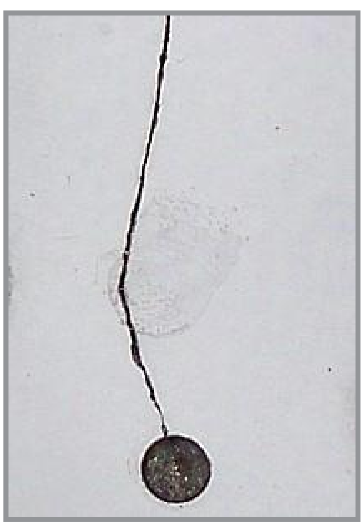
A crack is a type of discontinuity brought about by tensile stress the result being that things are no longer held together. This definition establishes that a crack is a sign of impending failure that prompts a course of action when found. You have to do something about it.

Stress ahead of visible end of crack **2. What to do about it?**

All detected cracks are a concern, regardless of their size. Leaving a crack in situ is rarely an option.
Many aircraft fly with known cracks if engineering demonstrates that the residual strength exceeds ultimate load; including crack growth until the next inspection. What to do about it is the decision of engineering presented through the aircraft's maintenance instructions. Most modern aircraft use a SEM (Structural Repair Manual).

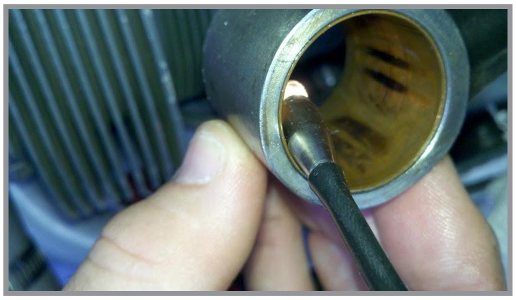
Crack from poorly drilled hole **3. Who's in Control?**

This is the key item of importance to the mechanic--the mechanic must defer to engineering or appropriate maintenance instructions as to the proper course of action when a crack is discovered. It is not in the mechanic's (nor aircraft owner's) area of expertise to access residual strength and crack growth rates.



Stop drilled and crack with patch behind **4. What is NOT a repair**
Stop drilling is not a repair; it's a temporary intervention. A stop drill hole does not properly restore the load-carrying capability of the structure and the underlying structural problem is still not properly addressed.
5. When Maintenance Makes the Decision Shortly before the right wing broke off of a Turbo-Mallard (N2969) killing all 20 people aboard, at a meeting with pilots the following comment was made: "the maintenance supervisor told them that the skin-cracks in the airplanes were superficial." NTSB accident report NTSB/AAR-07/04.

Lobing and other Low Frequency Form Error In Aircraft Piston Engines



"Overhaul to New Limits" -- what comes to mind? dimensions, sizes, clearances. That's it, right? At least that's all I hear discussed. Lets talk about Form Errors or errors in shape. These often cannot be detected using two-point micrometers and bore gauges -- the stock in trade of engine overhaul shops -- and frequently defines the limit of their investment in measurement technology!

Connecting Rod Bushing with Form Error Dark horizontal lines are contact points where the piston pin contacted the bushing. The pin should be bearing on a swept area and not on "high-spots"

To get you up-to-speed on Form Errors, I've put together a short video on one of the most common type of Form Error called "Lobing"

The take-away from the video is that there can be significant errors in form that cannot be detected using two-point measurement instruments (micrometers, calipers, bore gauges).

Diameter 1 inch - Shape Round Diameter 1 inch - Shape Lobe

A good example of this is a cylinder barrel. It can measure within new limits for dimension using a dial indicator but be way out of shape due to distortion and improper honing. For example, a barrel tends to wear on one side more than the other as one side is the "thrust" side that the piston pushes against as it rotates the crankshaft. Lets take that worn barrel into the shop where they "hone" it to a "new limit" but oversize dimension. Fair enough. But what has happened to the Form? Wear on one side of the barrel has in effect moved the barrel center line. The hone follows the worn barrel just making it bigger and round but does nothing to restore center line.

There are cylinder hones "rigid" ones that restore form. It is interesting to operate one as

the hone head does not float but is fixed to the proper position. Most hones, however, float or follow the existing hole which means that they may restore hole roundness but not form or position.

2.476 inches inside diameter at every point - but bad form I like to use a Slinky to demonstrate the difference between a dimension and a shape. Suppose that this represents your cylinder barrel; run a dial indicator down it and it measures 2.476 inches at any point you measure. But, as you can see the barrel is badly distorted. If your barrel is only 10 or 20 thousands of an inch distorted you would never know. -Your piston and rings would know as they attempt to adapt to the distortion as they quickly travel up and down the barrel; most likely resulting in poor sealing with high blow-by and oil consumption. The usual (incorrect) diagnosis based on these symptoms is "poor ring seating!" Take them off and hone to ring finish and try to seat the rings again with the same poor results. To prevent this expensive course of events one could carefully examine the wear patterns on the barrel for any tale-tell signs of wear. Based on this examination a course of action can be recommended with better results anticipated.

Another example is using a crankshaft belt sander to "polish" a crankshaft journal. Pretty typical process as long as we stay true to the purpose- polishing - and not sizing. As soon as we use the belt sander to dimension undersize (example go to 3 undersize on Lycoming due to wear) we introduce the possibility of form error. Form error also occurs when we "reface" rocker arm faces.

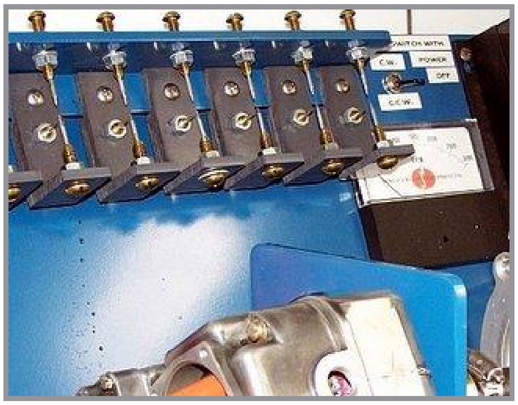
Observing Form Error

One of the best checks for Form is by observing wear patterns during engine tear-down -- do the parts "like" one another?
Engine Bearing with high spots The Bearing (backside view) shows horizontal stripes caused by machining/grinding the bearing boss with a gear driven tool rather than with a belt drive. Slight impulses from the gears create minute movements in the tool. This bearing doesn't like the boss regardless of the overall dimension.

One thing to consider when we talk about dimension and size. We measure at a few discrete points on a surface with infinite discrete points. 99% of the surface is not measured! One partial solution for this problem (and resulting form error) is to measure run-out whenever possible; we rotate the part while taking continuous measurements along a line. Run-out with a shaft mounted in a Vee block is the simplest method of detecting lobing in shafts.

More On the Problem of Lobing in Aircraft Engines

Magneto Test Bench Electrode Design



John,
I am building a magneto test stand and I'm wondering why there are typically 3 electrodes coming together at each spark gap? I would think only 2 are needed. For example, see the third contact at each spark gap in the photos below of other test sets. I am currently planning to only have two contact points at each spark gap unless there is a good reason to add the third.

Teaser Electrode extends from back of bar to lower electrode

The teaser electrode is used to solve the problem of time lag when using pointed electrodes (versus a spherical electrode). Time lag results in inconsistent voltage to produce an arc (voltage tends to be higher or overshoot without the teaser). This third electrode is universal used when measuring arc voltage across pointed electrodes.
The teaser electrode is insulated from the other two electrodes and is typically set to 0.1 mm gap from the main electrode (5 mm gap). As voltage rises on the main electrode a tiny arc (invisible) travels to the teaser which produces ionization in the main spark plug gap which helps set off the main arc.
Without the third electrode you have no method of comparing your results with book values since the spark voltage will be different and variable. I would add that I believe that the 0.1 mm gap distance has to be accurately set on all electrodes in order to get even sparking across leads.
A properly designed magneto tester with a properly operating magneto should produce such even sparks that the sound of the sparks is as regular as music. You should be able to detect a bad magneto from across the room with your back turned to the tester just from the sound of the arching.
See the following document for a more thorough analysis
http://naca.central.cranfield.ac.uk/reports/1925/naca-report-202.pdf

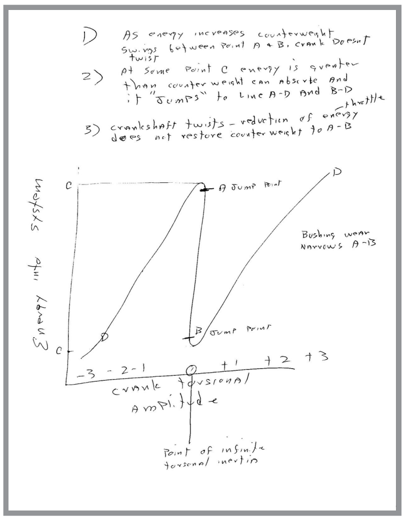
Lycoming or Continental Counterweight Detuning

Close-up of Lycoming counterweight showing plates (the part with 3 holes in it) that hold the pins in place. Pin diameter determines the pendulum length and thus the frequency.
"Counterweights" are used on 6 cylinder Continental and Lycoming engines.

Your engine produces power in descrete combustion pulses that twist the crankshaft. Between pulses the crankshaft springs back. If one were to freeze crankshaft rotation so just the vibratory forces were left you would see that the back of the crankshaft rotates in the opposite direction as the propeller! If these pulses are at the same frequency as the

natural frequency of the crankshaft then they have the capability of breaking the crankshaft at the fillet radius. In one test of a popular 6 cylinder aircraft engine, up to 20 degrees of crankshaft twist was measured!

Bifilar Pendulums (centrifugal pendulum vibration absorbers) aka "counterweights" pictured above absorb crankshaft torsional energy produced by the power stroke and eliminates or greatly reduces torsional twisting of the crankshaft.
There is a limit as to how much energy pendulums can absorb before they stop functioning. The graph below (I apologize for the poor quality) shows what happens when they are fed too much energy - Detune is the popular description although I prefer the word "jump".



Bifilar Pendulum Jump Curve

During normal operation the Pendulum(s) operate between line A and B. Within the limits of power the pendulum maintains crankshaft torsional amplitude (twisting) to near zero. The pendulum swings back and forth producing an opposing force to the twisting force thereby cancelling it out. Pretty neat trick.
What happens if we increase the energy beyond C? Energy is increased by increasing horsepower at the resonant frequency of the crankshaft (lets say resonance occurs at 2,200 rpm in our example). The pendulum "jumps" over to line D and the crankshaft torsional amplitude now is free to twist and untwist putting great stress on the crankshaft. The pendulums are in a state called "detuning". Not only is crankshaft stress much greater but the pendulum itself has stopped swinging on the pins and is instead rattling against its restraint. This can result in circlip and retainer plate failure that releases the pendulum. This is what happened to Cape Air/Nyannis Air Service Inc. in their Cessna 402 (reference Teledyne Continental Motors Service Instruction SSI07-5). In fact it has been found that a "jumped" pendulum can amplify vibration amplitudes.1.
Once the pendulum jumps (detunes) great stress and destruction is occurring inside the engine without any outward indication to the pilot. But what happens if the pilot reduces the power or changes the rpm? The pendulums stay detuned! Once they jump to D they can only be restored to proper operation A-B by reducing the power to close-to idle.
Wear to pendulum bushings reduces the jump point (A-B). Normal bushing wear (and abnormal fretting wear) inside the engine shifts the pendulum's frequency resulting in not only a lower jump point but a slanting of the A-B line thus allowing more torsional forces. One reason why I don't recommend running pendulum equipped engines past engine TBO.

Other failures possibly attributable to counterweight detuning:

- Impulse coupling attachment rivet failure
- Crankshaft cracking

- Propeller cracking
- Left magneto oil seal failure on some Lycoming engines
- Magneto drive shaft breakage
- Magneto distributor gear teeth failure
- Oil pump gear failure

What this means to the operator:

In the case of the Cessna 402 with TSIO-520-VB engines, don't operate at 2100 RPM and 27" Manifold Pressure (SSI07-5).

- Operate within the engine manufacturer's operational envelope.
- Ignore well-intentioned advise to operate these engines outside of the manufacturer's power/rpm recommendations.
- Pendulum bushing wear limits the safe operational service life of the engine.
- Modifications to increase engine power output put the pendulums closer to the jump point.
- Modifications to increase engine power output reduce allowable pendulum bushing wear limit.

Notes:

1. http://www.egr.msu.edu/dvrl/pubs/Nester-etal_HI04.pdf

2. Textron Lycoming Mandatory Service Bulletin No 245D

"Rapid opening or closing of the throttle can cause counterweight detuning…To avoid detuning during simulated engine failure, use the mixture control to shut off the engine and leave the throttle in normal open position until the engine has slowed down because of lack of fuel. Then, close the throttle to an idle condition. The throttle being open allows the cylinder to fill with air, maintaining the normal compression forces which are sufficient to cushion the deceleration of the engine. Another result of rapid throttle movement is severe strain on the supercharger gears and associated gears because of the inertia force of the high speed impeller."

Further reading:

Reduction of Periodic Torsional Vibration using Centrifugal Pendulum Vibration Absorbers Article on propeller interaction

Preventing Oil Leaks

The only reason we use gaskets is because we can't machine a truly flat surface. Bugatti engine blocks were hand scraped to ensure that the surfaces were so flat that gaskets were not required for sealing! Almost true - they were hand scraped but Bugatti engines did leak oil.

"... if they were perfectly flat and parallel to each other and stayed that way in operation, then no gasket would be necessary." Gaskets and gasketed joints - Page 90

I suggest that both of these statements do not tell the whole story when it comes to oil leaks at joints (gasket or no gasket).

Molecules and atoms travel across boundaries if the molecules or atoms are smaller than the voids present in the material. Two examples: a balloon filled with air soon deflates as the air molecules diffuse through the rubber, atomic hydrogen atoms diffuse into steel at a rate said to be similar to salt dissolving in water. This is the cause of hydrogen embrittlement in high strength steel. The key then to preventing leakage is by reducing the size of the voids to something smaller than the molecules we are trying to contain. Fortunately, oil molecules are much, much bigger than hydrogen atoms but they are much, much smaller than the tool marks on our faying surfaces.

No two surfaces are perfectly flat and parallel but even if they did exist there could still be voids that cause leakage. If the surfaces are perfectly flat and parallel, then how do voids occur? Through surface contamination. Surface contamination creates voids by two mechanisms:

1. Dirt and debris that prevent surfaces from clamping together. A classic example in our shop was a hair that we found lodged within the joint that prevented full seating on a non-gasketed joint.
2. Fluids (such as engine oil) coating the surfaces when the joint was assembled.

The first reason is self-explanatory as any particles prevent the surfaces from coming together. The second reason requires further explanation. Even perfectly flat and parallel surfaces wet with oil but fully clamped together are separated by a fluid film that allows oil molecules to travel through the joint.

Ordinary machined surfaces contain cutting troughs from the cutting or grinding tool that fills with oil, No matter how tight you make the joint the pliable gasket material cannot fill the void occupied by the incompressible oil. Voids occur where the gasket is pressed against the fluid film rather than the joint surface.

Oil travels across the joint by wicking or capillary action. Ordinary this is desirable trait of oil as oil will return when rubbed off a surface (example, ball bearing contact point where the oil is squished out of the way but quickly returns). In joints however, the movement of oil by capillary action presents a slow weep of oil. The fix is obvious, surfaces need to be clean, dry, and free of any oil. I suggest cleaning joint surfaces with a solvent such as MEK or isopropyl alcohol appled to a soft rag or even cotton ball. For example, when replacing a cylinder on an engine, the crankcase mating deck is often wet with oil. Clean and dry both the crankcase deck and the cylinder mounting flange.

Also, don't forget to inspect the surfaces for flatness and parallelism. *See Also: Oil Leaks -- It's not the gasket, it's the surface*