Lead Fouling

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I have had a lot of quesitons about Lead Fouling of engines in the past and this is a good opportunity to explain how it happens and how to help avoid it.

As you will know. Avgas 100LL contains a compound known as Tetra Ethyl Lead (TEL) which acts as an octane booster for the fuel. This results in a fuel which is commonly known as a 100 Octane lean mixture and 130 rich mixture Performance Number fuel.

In practice it is even better than this, with ratings more like 106 lean mixture & 130 rich mixture which are far in excess of the comparable 85-87 octane of road fuels. To achieve this a lot of TEL is used – around 5 times the quantity that was used in the old Leaded automotive fuels.

This increase in octane allows aviation engines to produce more power through increased compression ratios or alternatively by increasing the inlet pressure by using a turbo or a supercharger. The problem with using Leaded fuels is that they will always burn with more deposits than unleaded fuels.

The Tetra Ethyl Lead used for octane boost in the fuel naturally degrades to form Lead Oxide when it is burned. In reality it is this oxide which gives the octane boost. The problem is that Lead Oxide is solid up to about 900 deg C which is well within the wall temperatures inside a piston engine.

In order to prevent these deposits from forming, a Lead scavenging compound is added to Avgas 100LL – this compund is Ethylene Dibromide. This scavenger is designed to react with the Lead oxide to form Lead Bromide which is more volatile – becoming a gas at around 200-250° C. This is a low enough temperature to ensure that the Lead is removed from the engine as a gas end it subsequently goes back to the solid phase as the exhaust gas cools in the atmosphere.

As a point of interest the pale brown/ash coloured staining that is often seen leading from the exhausts of high powered engines, such as those found on the warbirds, is in fact Lead Bromide.

To enable this reaction between the Lead Oxide and the scavenger to work, there needs to be a relatively high combustion temperature.

What a lot of people do is conduct the warm up with the engine power lever on the idle stop, and this is inappropriate. The technique for the common Teledyne Continental Moters and Textron Lycoming General Aviation engines is as follows.

After start up, the engine should be operated at 1000-1200 rpm for the initial warm up period and not at the 600-650 rpm idle speed. This serves a number of purposes.

The higher cylinder pressure encourages the rings to seal properly, not only limiting oil egress into the combustion chamber, but also reducing the amount of corrosive combustion by-products going the other way into the sump oil. This technique thus also helps reduce the risk of corrosion problems in the long term by reducing the amount of acids and Lead being pumped into the oil.

Meanwhile in the combustion chamber, Lead Oxides tend to form deposites because of the low combustion temperatures. The temperature for Lead deposits to frorm tend to be favourable around the spark plugs (as the whole mixture is quite cool before the flame starts to propagate) and on the exhaust valve stem (as the mixture cools after combustion).

The problem is that the deposits are electrically conductive, which shorts out the spark plug – and corrosive, which can start to attack the metal of the valve stems.

Temperature is a key factor in preventing Lead fouling and it is not just at start up, but also the correct shut down procedure should be carried out.

Engines that have been involvd with long, low power descents or have taxied from some distance, can have quite low cylinder temperatures and this – as we now know – can lead to lead fouling. Again the advice from Textron Lycoming and Teledyne Continental Motors to remedy this is: once on the aircraft is on the stand, the engine speed should be kept between 1000 and 1200 rpm once again and then immediately shut down using the mixture control.

Spark Plugs

If problems persist, then another questions to ask is are the plugs of the correct type? Check the charts for your engine, but generally a hotter plug should be used in a lower powered engine. Higher powered engines tend to generate enough combustion temperature to keep the spark plug nose hot, and there for deposits down, even with cold plugs.

A hot plug does not transfer heat rapidly away from its firing end into the cooling system and is therefore better at avoiding fouling where combustion chamber or cylinder head temperatures are relatively low. In order to achieve this, hot plugs have a relatively long insulator nose with a long heat transfer path.

With the Tempest plugs, the higher the number, the hotter the plug, for example the UREM40E is hotter than the UREM38E.

Some of the spark plug manufacturers have some other solutions too. If we look at the example of a Tempest UREM37BY plug which is recommended for most of the Lycoming O-320 and O-360 engines, this plug does not prevent the accumulation of Lead deposits, but its design is supposed to make it capable of firing even with severe Lead deposit build up.

This problem can also be an issue with Microlight engines such as Rotax 912's. These engines are designed to run on unleaded fuels, but they will run on Avgas 100LL – indeed Public Cat aircraft, such as Rotax engined Diamond DA-20's used for flight training, for must run leaded Avgas 100LL. A similar trick can be emplyed with this engine too when using Avgas 100LL.

If you are running a Rotax 912, using the recommended NGK DCPR8E plug and you find it is fouling then try using a hotter plug like the DCPR7E (also allowed by Rotax). This should help as the plug tip will run hotter and discourage the Lead Oxide deposits from forming.

There is a limit on how hot a plug should be used, the plug tip can become so hot that the plug itself becomes a source for fuel pre-ignition, which can cause engine damage.

One final question to consider is, are the plugs rotated regularly? It is common knowledge that the lower plugs in an engine will run dirtier than the top plugs even in normal operation, and rotating plugs every 25 to 50 hours is recommended by the engine manufacutrers. This results in a self cleaning action, but the plugs should always be swapped in magneto sets as the plugs temselves can herald clues about he magneto condition. Swapping the plugs randomly loses this information.

Hopefully this helps in expanding on some of the myths of Lead fouling and helps you avoid being its victim in the future.

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