Modern Petrol and Classic Cars - the Manchester XPAG Tests

Introduction to the project

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Even if your classic car runs well on modern fuel, the chances are you know somebody who has problems. The most common issues people suffer from is called the “Hot Restart Problem”. Drive your car any further than 10 miles or so, stop for 10 minutes for example to fill up with petrol and when you get back your car it will not start. A related problem occurs if you are driving in slow traffic, especially on a warm day, the engine coughs and splutters to a stop as though it has run out of fuel.

These are the most obvious problems with modern fuel. There are others which people have reported including burned exhaust valves, cracked cylinder heads not to mention the worries of ethanol blended fuels.

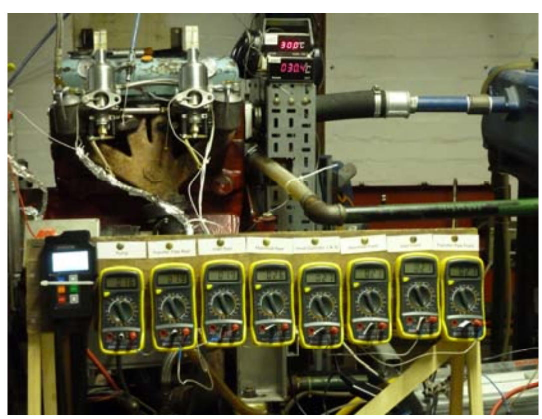
I have owned my MG TC since 1967 and, for those who can remember back that far, used to run it on 2 star leaded fuel. It ran like a dream. My problems started after the demise of leaded petrol and have resulted in a great deal of time spent in the garage trying to sort them out.

Around 15 years ago, I realised my problems were caused by differences in the composition of modern petrol and started testing different concoctions and types of petrol in my TC and writing articles about my findings. These tests culminated in a student engineering project at School of Mechanical, Aerospace and Civil Engineering (MACE) who installed an XPAG engine similar to the one fitted in my TC in an engine test cell aimed at investigating these problems. Unfortunately, the students ran out of time before completing the tests. The good news is that with additional support from the MG Car Club and help from MACE, these test have been completed providing a fuller understanding of the problems caused by modern fuel, things that can be done to mitigate them and, on the way, debunked a few myths.

Thanks must go to Andrew Owst who loaned the engine, David Houghton who came out of retirement to manage the test cell and those who gave up their time to help with running the tests. Thanks must also go to the MG Car Club, Burlen Fuel Systems, Totally T Type 2, Octagon Car Club, Federation of British Historic Vehicle Clubs (FHBVC), MG T Register, MG Y Register, Anglo American Oil Company, NTG, Distributor Doctor, 123ignition who have sponsored this project either financially or by supplying parts or fuels.

Why an XPAG?

Almost the first thing people say is “why test an XPAG, they are an old engine, designed in the late 1930’s and only fitted to MG T Types”. While it would have been ideal to test a range of engines, the high cost of installing the engine in the test cell prevented this. In practice, the XPAG or 'X' series engines were used in virtually all Morris and Wolseley cars until 1956, including the many thousands of the Morris 10/4 Utility cars & vans made during WW2.

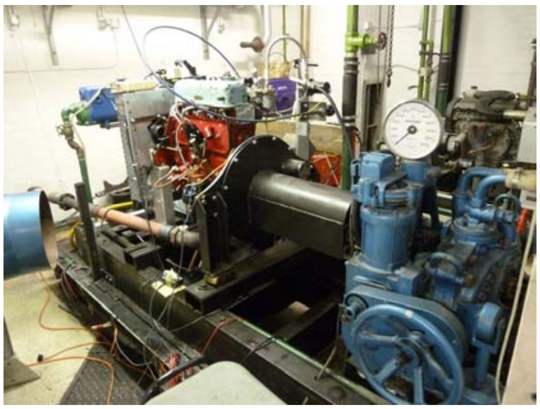


Engine and measuring equipment

The XPAG is a good compromise. Its long stroke bottom end shares a great deal with earlier engines, while the cylinder head design is virtually identical to the A and B series engines fitted to later cars. It also demonstrates the problems running with modern fuels very well.

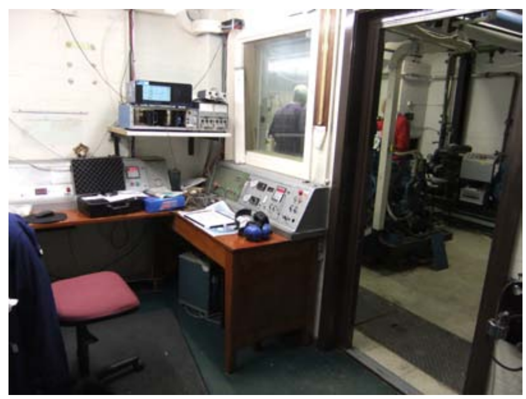
What is wrong with a rolling road?

Other people have asked why not use a rolling road? The dynamometer at MACE provides the ultimate test cell for an engine. The engine is fully accessible allowing a range of thermostats, vacuum gauges and exhaust gas monitors, etc. to be fitted. In addition it is easy to change the fuel that is being used. The throttle setting can be fixed and the revs controlled by the dynamometer enabling part throttle as well as full throttle conditions to be investigated. This setup allowed a very large amount of data to be collected for many different scenarios.


Dynamometer

The picture above shows the engine hiding behind a set of meters with the air fuel ratio meter on the left hand side and an array of 8 yellow temperature meters connected to thermocouples on the fuel pump and carburettors. At the top right are the temperature readings for the water and exhaust gasses. The rectangular blocks on top of the carburettors are to allow the height of the piston to be measured and you can just see one of the vacuum gauges connected to the inlet manifold to the left of the rear carburettor.

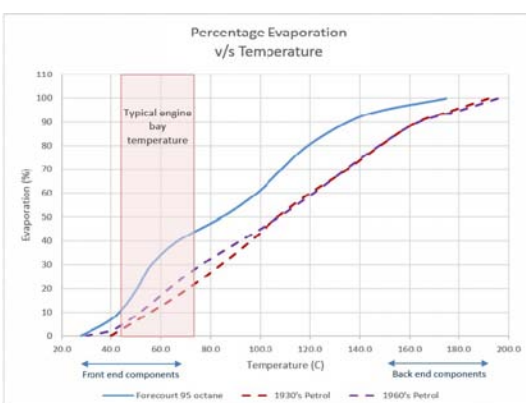
The picture above shows the water braked dynamometer with its large RPM gauge. This was managed from the control room where the gas analyser and various other readouts were located.


Control Room

As the pictures show, there is a lot more you can do with an engine installed in a proper test cell than you can with a rolling road.

What is the cause of our problems?

Modern fuel is different from classic petrol in two main ways. Firstly it most probably contains ethanol and secondly it made from of a much wider range of hydrocarbons.



Components of modern fuel (Source BP)

Crude oil consists of many different hydrocarbon molecules. When heated, these molecules boil off at different temperatures, lighter ones evaporating first and the heavier ones at higher temperatures. Crude oil is cracked, by heating and condensing out the components or distillates over the different temperature ranges, for example light gasses such as propane and butane are condensed at lower temperatures, petrol at higher temperatures, diesel at higher temperatures still and tars at the highest temperatures.

With a wide range of distillates modern petrol starts to evaporate or boil at lower temperatures than classic petrol and the high boiling point components require higher temperatures to evaporate.

Before petrol can burn in the cylinder of a car, it must be a vapour. While the low temperature distillates make starting a cold engine easier, they are the sole cause of the "Hot restart problem". Some of these evaporate well below the operating temperatures of engines and under some circumstances will boil in the fuel system and carburettors stopping the engine running properly.

This will be covered in more detail in a future articles.

Ethanol

In the UK up to 5% ethanol alcohol is blended with petrol, in France this can be up to 10% with even higher levels in other countries.

Adding ethanol to petrol is not new. Cleveland Discol was introduced in 1928 and sold until 1968 claiming to "contribute to a brilliant performance and better mileage because it keeps the engines cooler and cleaner", "the perfect cold-weather fuel". However, it is not known what percentage ethanol Cleveland Discol contained making it difficult to compare with modern fuels.

Were Cleveland's claims true? An E10 blend of fuel obtained in France was tested in Manchester and the report of how the XPAG ran on this fuel will appear in the Engine performance article.

There is a large amount of published information about ethanol blended fuels and their potential damaging effects to fuel hoses, seals, etc. however, probably the most worrying problem is their ability to corrode metals such as steel and aluminium.

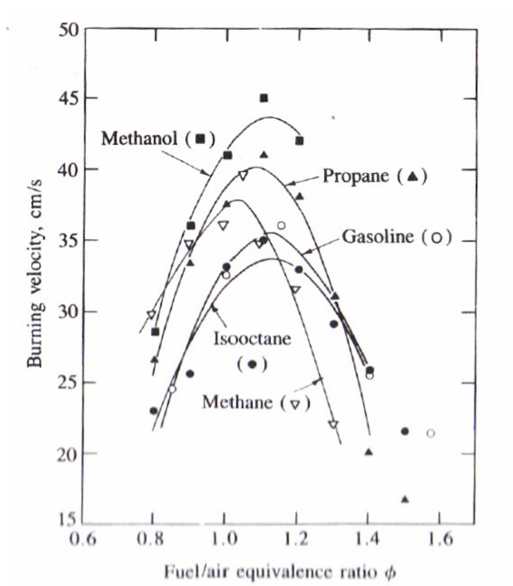
Hoses are relative cheap and easy to replace, carburettors, fuel pumps and the like, far more expensive and for older cars, parts may no longer be available.


Corrosion in float chamber

Is corrosion of metal components really a problem?

You can see the corrosion at the bottom of one of the float chambers in my TC. Especially worrying as I have been using premium blend fuels that I thought were ethanol free fuels for the past 6 years.

There are two different types of corrosion; one where the metal is attacked usually by an acid: the second requires two different, electrically connected metals in a conducting medium, called an electrolyte. This arrangement forms a battery and as the current flows, the anode corrodes. This is called galvanic corrosion.



Ethanol blended fuel causes both these corrosion. The corrosion in my float chamber was around the steel bolt connected to the aluminium body, suggesting it is galvanic corrosion. There is little information on the protection offered by the additives against galvanic corrosion and is something I will investigate further this winter.

Do classic cars run as well on modern fuel?

How many times at natters have you heard statements such as "modern fuel burns more slowly" or "the higher the RON number, the faster the fuel burns" or "modern fuel burn hotter"? While none of these statements are true, they underlie a feeling that classic cars do not run as well on modern fuel.

The way petrol burns in the cylinder is very complex. An overview of this process helps in understanding why classic cars can run hotter and why modern fuel apparently burns more slowly.

The graph, from a research paper, shows the burning velocity (flame front speed) of different hydrocarbons plotted against the fuel air equivalence ratio. Air equivalence ratio is defined as 1 when there are the exact number of oxygen molecules in the mixture to allow each of the hydrogen and carbon atoms in the fuel to oxidise or burn. Optimum power is produced at an air/fuel ratio of around 0.95 (or 1.05 on the graph as this shows fuel/air ratio).

While the flame front speed in different hydrocarbons is small, it is very sensitive to the differences in air / fuel ratio. What is also interesting to note is the fastest flame front speed in Gasoline (Petrol) is a very sedentary 35cm/sec.

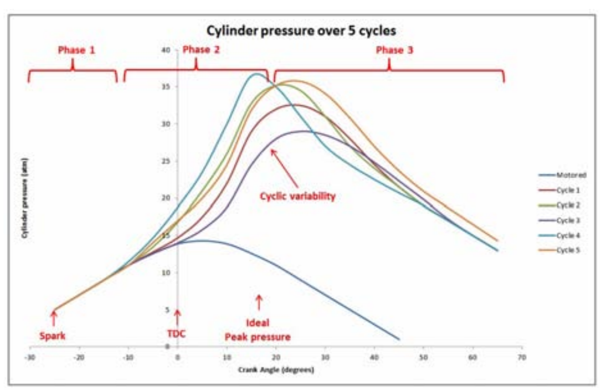
The bore of an XPAG engine is 6.67cm. At a speed of 35cm/s, it would take 0.2 seconds for the flame front to cross from the spark plug to the other side of the cylinder. If this were the only factor in burning the fuel, it would limit the engine to a maximum of 50rpm! The only reason spark ignition engines can run at high revs is because turbulence in the gasses mixes the flame front in the cylinder allowing the burning to spread out more quickly. The turbulence of the air / fuel mixture in the engine is a function of design of the head and inlet manifold and not the type of fuel being used.

There are three phases during the combustion cycle. Firstly, when the spark plug fires, a fireball of burning mixture about the size of a pin head is created. This fireball grows as the flame front moves outward at approximately 35cm/sec depending on the pressure in the cylinder and air / fuel mixture around the spark plug. This initial phase of the combustion is slow and a significant factor in the time taken to burn the fuel. Once the fireball has grown to approximately the size of a pea, the second phase begins when turbulence starts to take over and spreads these ignition points throughout the volume of the cylinder rapidly igniting the remaining mixture and raising the pressure in the cylinder. Finally, any fuel which did not initially evaporate or was trapped around the valves or piston burns in the extremely high temperatures created during the second phase.

It takes a relatively long time it takes from the spark that creates the initial fireball to all the mixture being burned. As revs increase it is necessary to advance when the spark plug fires to provide sufficient time for the fuel to fully burn before the optimum timing when the piston is approximately 17 degrees after top dead centre. On very early cars this was achieved manually, on later cars and the majority of MGs this is done by bob weights in the distributor which fly out as engine revs increase, causing the ignition timing to advance.

There is also a second effect. The growth of the initial fireball is dependent on the pressure of the mixture in the cylinder which in turn depends on throttle setting. At light throttle settings, cylinder pressure is low and the growth of the flame front slower. This requires the timing of the spark to be further advanced for light throttle settings. On later cars this is achieved using the vacuum advance pod on the distributor which is connected to the inlet manifold. A light throttle setting reduces the pressure in the inlet manifold causing the pod to advance the ignition timing. Earlier cars do not have a vacuum advance.

The tests at Manchester have shown how important correct ignition advance is in allowing the engine to run cooler.



Three phases of combustion

Cyclic Variability

A weak or rich mixture around the spark plug slows the growth of the initial fireball. This can have a significant effect on the timing of combustion cycle. Even if the carburettor is set to deliver the perfect fuel / air mixture, there is no guarantee that, after the compression stroke, the mixture around the spark plug is correct. It is quite possible it will be either too weak or too rich depending on how well the fuel is atomised in the carburettor, mixed with the incoming air and vaporised during the compression stroke. A slow growth of the initial fireball leads to retarded combustion of that cycle. The graph above are the results of cylinder pressure measurements in a running engine and show a difference of some 10^{o} difference between the timing of the peak pressure.

Cycle by cycle variations in the mixture of the small volume of gasses of around the plug when it fires and subsequent changes to the speed at which the initial fireball grows, leads to a phenomena called Cyclic Variability. The timing of each combustion cycle varies every time that cylinder fires. Even with a perfectly tuned engine with the correct centrifugal and vacuum advance, cyclic variability causes a percentage of the combustion cycles to burn too slowly as though the engine is running retarded, increasing the temperature of the hot gasses leaving the exhaust.

The other effects of cyclic variability are that it causes an engine to run roughly and slightly reduces power output, normally something most people will not notice. However, large cyclic variability will noticeably increase the temperature of the exhaust gasses and under bonnet temperatures. It is worth trying different fuel suppliers and blends and noting how smoothly your car runs. Should you find one on which your car runs more smoothly, use that as a preference.

Where do we go from here?

With the exception of the corrosion caused by ethanol blended fuels, the problems caused by the low boiling point of modern fuels and cyclic variability are related. Cyclic variability leads to more heat being generated in the cylinder head and exhaust which raises under bonnet temperatures which in turn make the problem vaporisation of the low boiling point components of modern fuel worse.

Slight differences in tuning, use of different brands of fuel, etc. can reduce cyclic variability, under bonnet temperatures and the impact of the low boiling point components in the fuel. This is probably why the symptoms of the problems, such as the Hot Restart problem, can vary between seemingly identical cars.

Initial tests with my TC using the findings of the Manchester tests are encouraging. Further articles will be published covering the Manchester tests in more detail, reporting on the findings and suggesting ways to make classic cars run better on modern petrol.

Paul Ireland