Manchester XPAG Tests

Part 5 - The Problems with Modern Fuel (2)

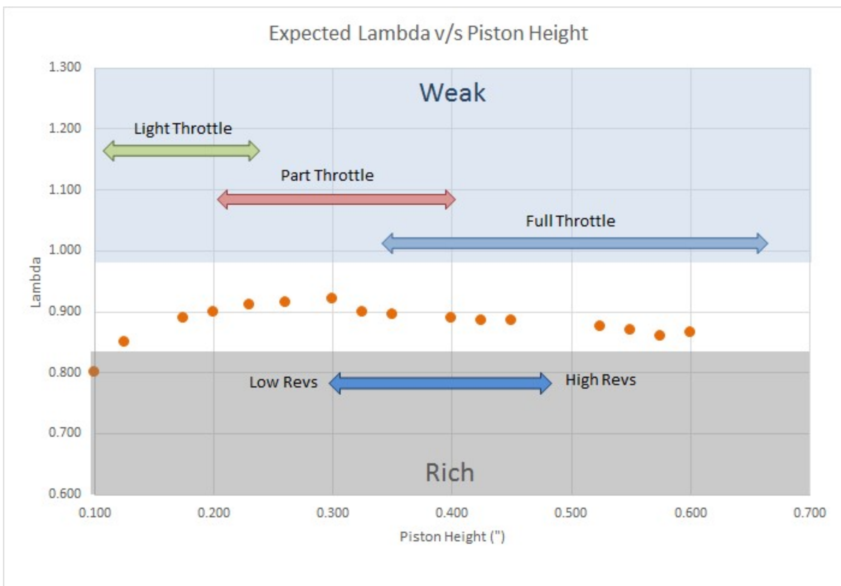
Introduction

In the previous article, I described the first of two problems caused by modern petrol *Weak Running* and discussed how the Manchester tests had shown a second problem, *Slow Combustion.* This article describes the *Slow Combustion* effect and the evidence from Manchester that suggests the cause of this problem.

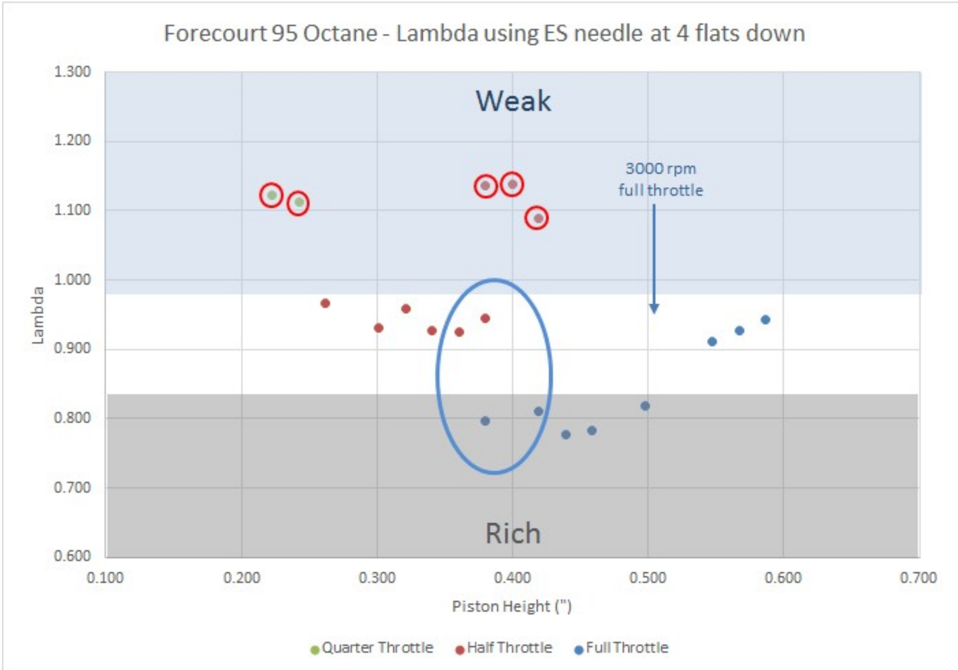
Running Lambda

To remind readers. The carburettor suction piston heights give a direct measurement of the volume of air / fuel mixture flowing into the engine and the profile of the tapered needle controls the volume of fuel leaving the jet for each suction piston height.

The graph below shows an ideal plot of how Lambda would be expected to vary with carburettor piston height where each dot represents an engine RPM / throttle stetting that corresponds to that piston height. The white horizontal band is the ideal range for lambda. Lambda values greater than 0.98 represent a weak mixture and less than 0.83 a rich mixture.



Even though Lambda was set to 0.95 for each test at Manchester, it is possible to calculate what Lambda would have been delivered if the engine had **not** been retuned. The graph below shows this data with the jet adjusting nuts set at 4 flats down from fully closed, running with a standard ES needle and using the same brand of 95 octane petrol.



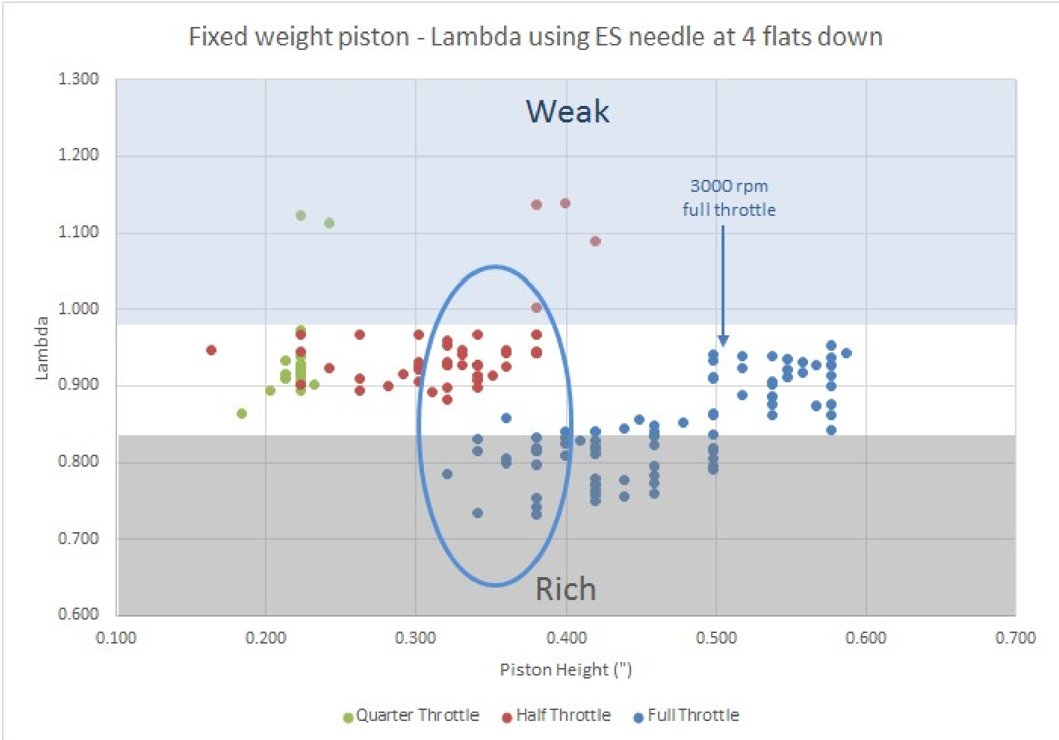
The first thing to notice is this graph looks very different from the ideal above. The five points circled in red (two green, quarter throttle and three red, half throttle), correspond to the carburettors delivering an exceptionally weak mixture which was discussed in the previous article.

The four points in the blue circle, on the above graph, show the carburettors delivering **different** lambda values for the **same** piston height. Simplistically, this is not possible as the volume of fuel is determined by the needle diameter at that piston height, i.e. same piston height, same volume of air, same volume of fuel, hence the lambda values should be the same. These provide the evidence for the *Slow Combustion* problem.

Slow combustion

Slow combustion is something David Heath and I postulated as a problem with modern petrol after running various tests using our TA and TC cars. Anomalies in the carburettor test data and other test data support this view. However, while I refer to the problem *Slow Combustion*, modern petrol does not **actually** burn more slowly than classic petrol, this is an apparent effect caused by cyclic variability discussed in previous articles.

This effect can be seen more clearly on the data from all the test runs (below) in the region, highlighted by the blue oval. At piston heights between 0.3” to 0.4”, the full throttle tests (blue dots) consistently show a richer mixture than the half throttle tests (red dots).



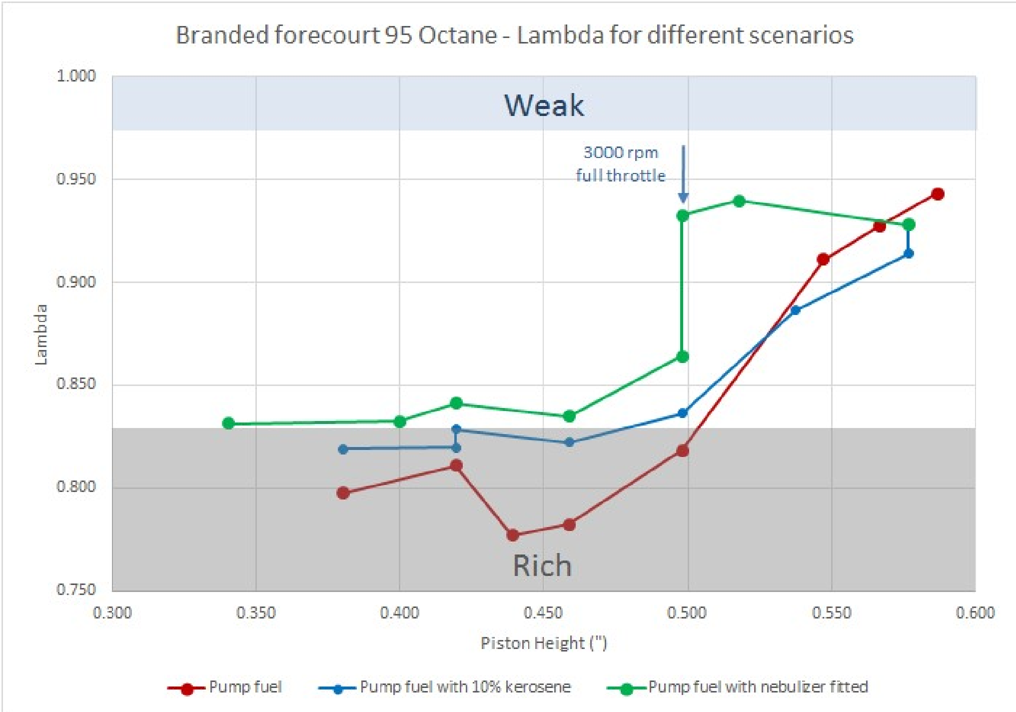
The Suck, Squeeze, Bang and Blow article helps to understanding this. The airflow through the carburettor is not constant, it is pulsed as each cylinder undergoes its "suck" cycle. With a single carburettor, there are two "sucks" per rev, and one "suck" per rev with a twin carburettor engine. The gases in the inlet manifold and inertia of the suction piston normally act to smooth out this rapidly pulsing airflow allowing the carburettor to function as expected. However, readers will remember "valve overlap" where the inlet valve starts to open in advance of top dead centre during the final phases of the exhaust stroke.

If the charge of fuel burned "slowly", the pressure in the cylinder will be high when the inlet valve opens resulting in a pressure pulse entering the inlet manifold. This pressure pulse causes the suction piston to drop so that it is too low when the next induction cycle starts. This, in turn, causes the carburettor to deliver a richer mixture. The data clearly shows this effect for the full throttle tests below 3000rpm. Indeed, during some of the full throttle, lower rpm tests the suction piston could be seen to be vibrating around a point rather than floating at a fixed height.

As engine revs increase so does the velocity of the air flowing through the carburettor and the turbulence. This improves the breakup of the petrol droplets and their dispersion in the air stream, which in turn reduces the magnitude of the cyclic variability and size of the back pressure pulse. This is why the mixture can be seen to be returning to normal as piston height (engine revs) increases, ultimately, delivering the correct lambda of around 0.95 above 3000 rpm, full throttle.

These tests support the "modern fuel burns more slowly" comment made by many classic car owners, however, this problem only occurs in the XPAG on high throttle settings below 3000rpm.

Supporting evidence for the slow combustion hypothesis comes from the other test runs with the same branded 95 octane fuel. In one set of test runs a nebulizer was fitted into the inlet manifold, in another set, 10% kerosene was added to the petrol. The graph below shows the full throttle data for these tests where each dot represents one test run.

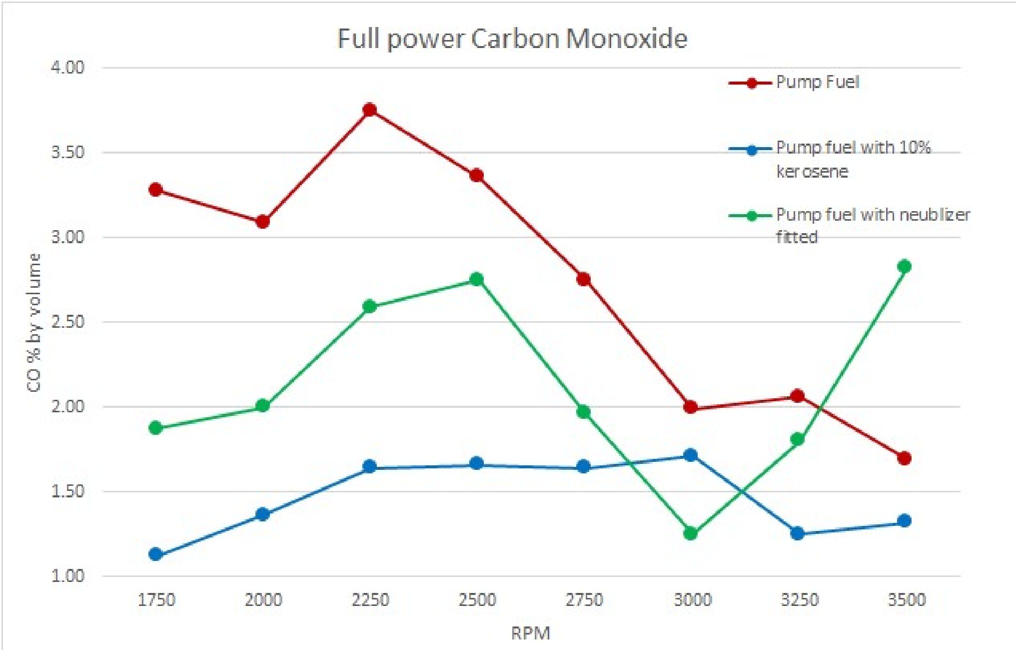


What can be seen is that, below 3000rpm, the enrichment caused by slow combustion is significantly reduced by the nebulizer (green line) and by the addition of kerosene (blue line) compared to the tests with the 95 octane petrol alone (red line).

The main effect of the nebulizer is to atomise the petrol and improve its dispersion before entering the engine, in much the same way as a fuel injection systems. Better atomisation reduces cyclic variability, the number of late combustion cycles, the magnitude of the back pressure pulses and their effect on the carburettor. Ultimately, reducing the enrichment of the mixture below 3000 rpm. The addition of kerosene appears to have a similar effect.

When I originally tested adding kerosene to petrol with my car on a rolling road, all present comment on how much smoother the engine sounded. This I attributed to a reduction in the magnitude of the cyclic variability, something now demonstrated by these tests.

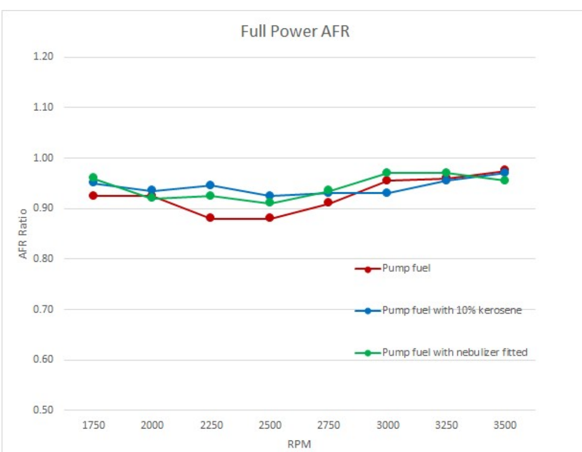
Other evidence comes from the carbon monoxide emissions. In Suck, Squeeze, Bang and Blow, I described how high levels of carbon monoxide in the exhaust are an indicator of poor combustion. As the engine was fully re-tuned for every test, the levels of carbon monoxide are not an indicator of a poor state of tune and only reflect what is happening in the combustion process. High levels of carbon monoxide are the result of poor mixing where pockets of rich mixture do not burn properly. The graph below shows the carbon monoxide emissions for these same tests. On this graph the lower the levels of carbon monoxide, the better the engine is running.

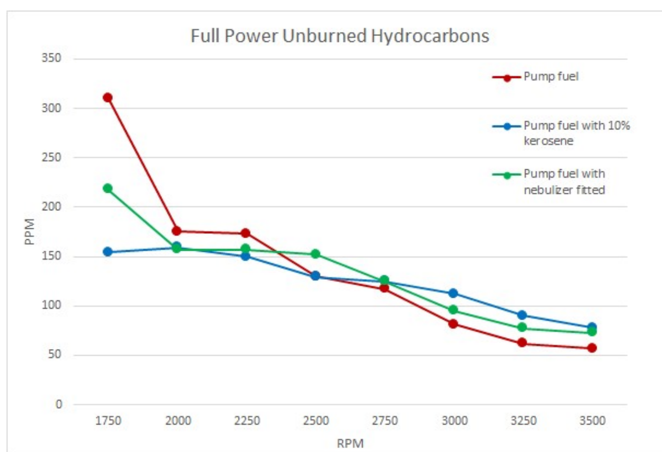


Again, below 3000rpm, the results are striking. The test run with the 95 octane petrol (red line) produced almost twice the level of carbon monoxide as that produced by the tests run with the same fuel but with the nebulizer and added kerosene (green and blue lines). Interestingly, this data suggests the combustion is more complete with kerosene than with the improved mixing produced by the nebulizer. I do not have an explanation for this.

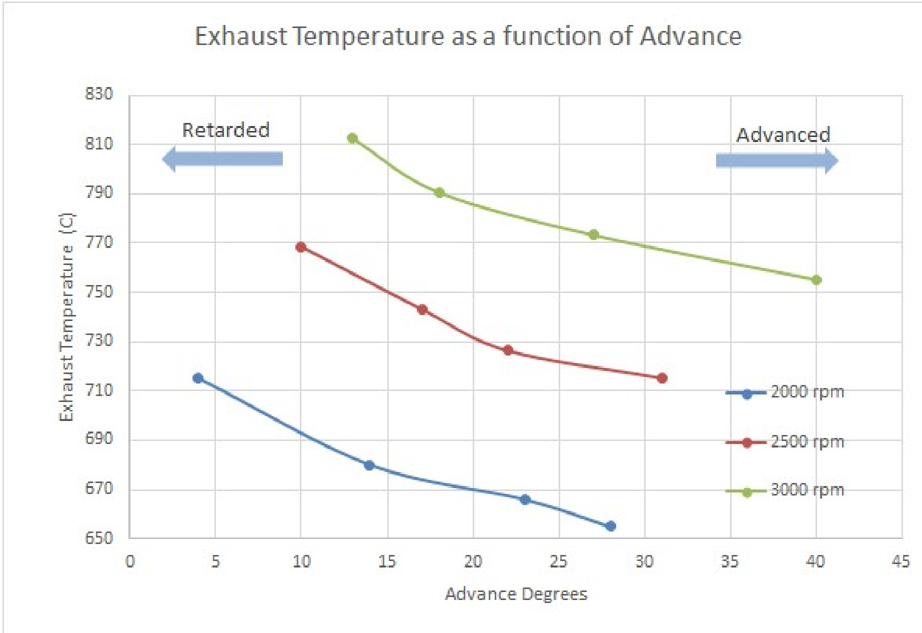
Above 3000 rpm full throttle, where slow burning does not appear to affect the engine, the nebulizer and addition of kerosene have a lesser effect.

As the engine was retuned for each test, the differences highlighted above are not due to changes in mixture as is shown by the virtually identical values of Lambda and unburned hydrocarbon data for these tests. Hence, the differences in carbon monoxide can only be the result of changes in the combustion process.





The final supporting evidence comes from large reduction in exhaust temperatures as the ignition is advanced, reported in an earlier article. Advancing the ignition timing reduces the number of cycles that occur late and the volume of fuel burning in the exhaust.



Although there is no data covering throttle settings between half open and fully open, it can be assumed that as the throttle is opened the magnitude of this slow combustion problem will increase until it reaches the level shown by the full throttle tests.

The negative effects of slow combustion is to increase exhaust, cylinder head, exhaust manifold temperatures and ultimately the under bonnet temperature. All factors which contribute to the hot restart problem. Additionally, hot inlet and exhaust valves can cause pre-ignition or pinking seen in some engines. Unfortunately, slow combustion occurs in the rev range between 1750 to 3000 rpm at part to full throttle, conditions typical of normal road driving.

Conclusion

This data from the Manchester XPAG tests clearly demonstrates two problems with modern fuel that ultimately lead to the hot restart and "overheating" problems that many classic owners suffer from.

The temperature measurements show the engine carburettors typically run at temperatures very close to the point where the *Weak Running* problem will become prevalent. When an engine stops, the tests also show that hot gases leaking back into the carburettors from open inlet valves can make matters worse and are probably a significant factor that contribute to the hot restart problem.

Slow Combustion compounds matters particularly at normal road driving speeds, by increasing cylinder head and exhaust temperatures and ultimately the under-bonnet temperatures.

But all is not doom and gloom, the tests have also suggested ways in which these problems can be mitigated. Wait for the next articles