The Benefits Of Platinum Based Additives For Particulate Filter Application

Authors
D Spivey, M Macduff, A Panesar.

Introduction
Additives for diesel particulate filter regeneration (trap additives), are added to the fuel on a constant basis. They generally contain a catalytic substance such as a metal, that survives the combustion process and ends up intimately mixed with the particulate trapped in the exhaust particulate filter. Here they are positioned to catalyse the burning off of the trapped particulate and thus enable the diesel particulate filter to function more efficiently and in more applications.

This paper discusses some of the additional benefits from trap additives that include a small amount of Platinum in their composition.

Benefits Discussed
The following benefits are discussed in this paper:

- The impact of balance point step length on balance point
- The impact of substrate on balance point
- Some interesting combinations of technology
- The impact on emissions of NO2
- The impact on emissions of Carbon monoxide, both with and without conditioning
- The impact on fuel economy

All these subjects contribute to a better understanding of the general impacts of test methodology, hardware interaction, cleaner total exhaust emissions and improved efficiency from these additives.

The test work was done using VW TDi and OM 364LA bench test engines at the Hazelwood laboratories. These engines are representative of a wide usage in the field.

Test Setup & Methodology
The testhouse at Hazelwood is equipped with individual test cells as shown in the 2 photographs below.

Figure 1
A bank of engine test cells at the Hazelwood laboratories

Figure 2
The outside of the test cell housing the VW TDi. The control panel can be seen on the left.

The VW TDi engine itself is shown in Figure 3, with the key parts, all of which can be seen, labelled.

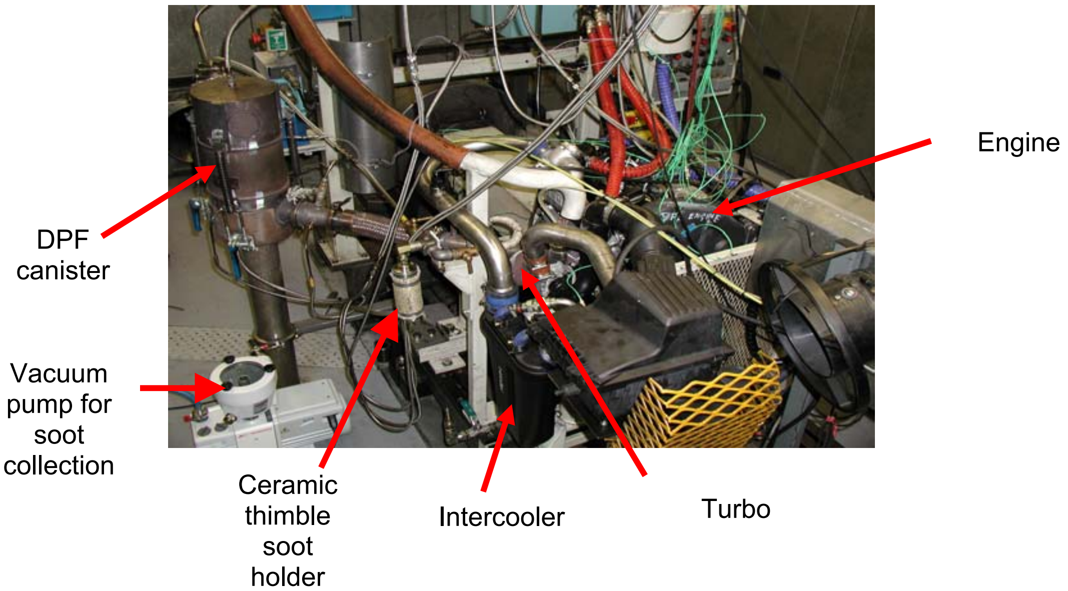


Figure 3 – The VW TDi engine used for testing

The VW TDi engine used was 1.9 litre displacement, 81 kW power, 4 cylinder direct injection with both turbo charging and intercooling.

The dynamometer used was a Froude 150kW Type AG150.

For emissions measurements, a Test 350 emissions analyser was used.

Figure 4 provides a schematic of the full test cell layout.

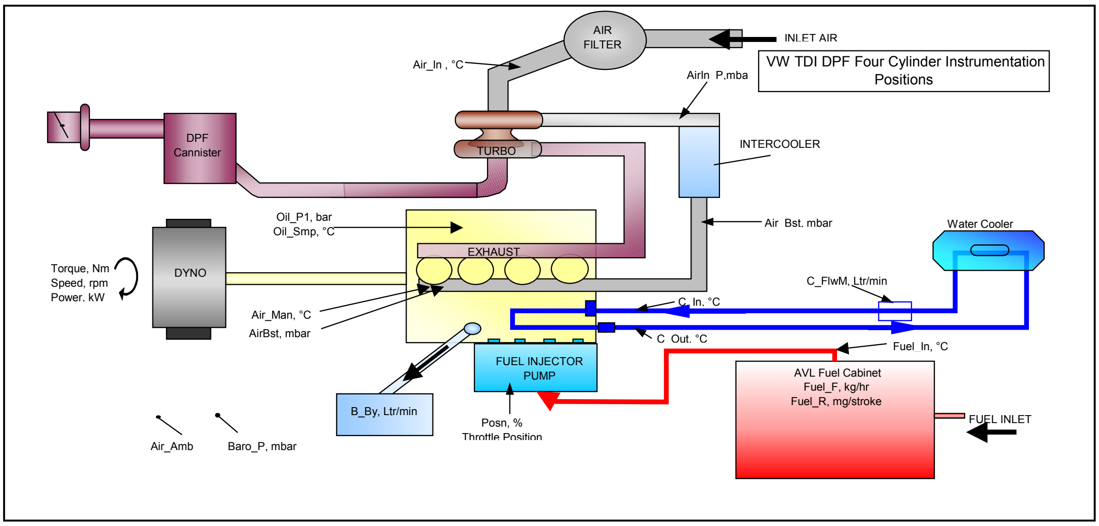
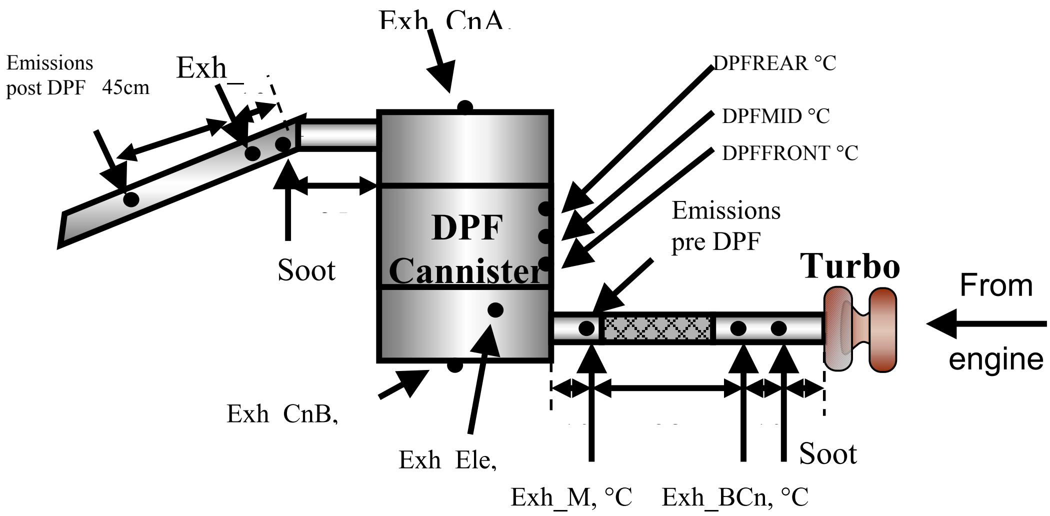


Figure 4

In Figure 5, a more detailed schematic of the setup around the diesel particulate filter cannister itself is provided. It is worth noting precisely where the emissions measurements are taken. Also, not that the temperature of the filter is recorded off the front face of the monolith.

Figure 5 – measurement points in and around the diesel particulate filter cannister.



For the test work, CEC RL128 engine oil was used.

Prior to running balance point tests, preparation and sooting runs are done. These ensure that the particulate filter is firstly purged of accumulated soot from previous tests, and then that a set amount of soot is accumulated in the filter using the fuel to be tested.

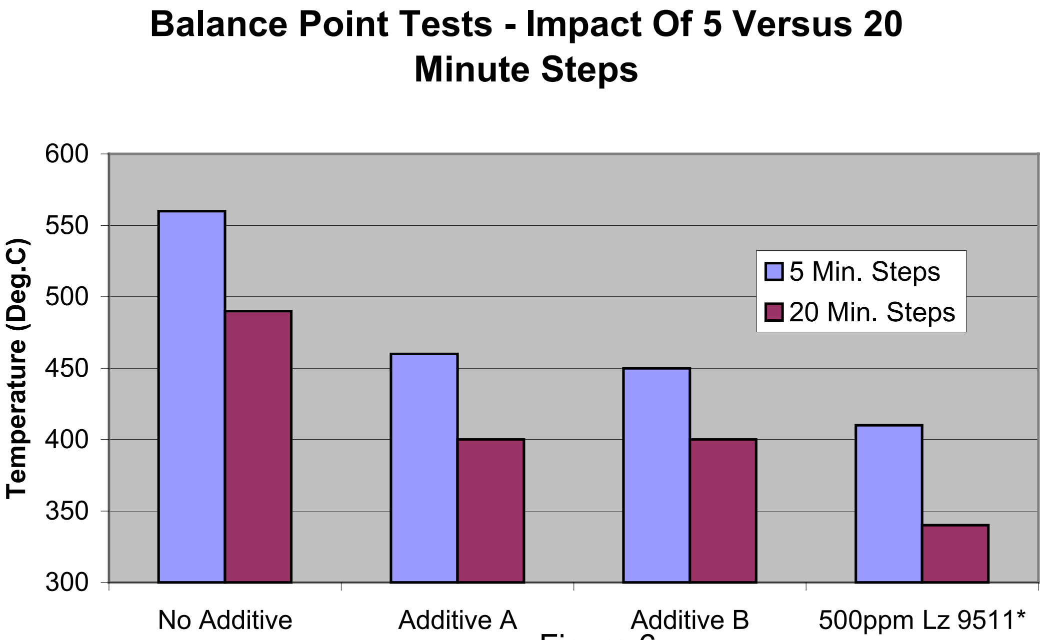
For preparation, the diesel particulate filter is run in the engine exhaust at 600 deg.C for 2 hours, and purging double-checked through a weighing after 30 minutes of cooling time.

The soot is then accumulated in the filter, by placing it in the engine exhaust at 200 deg.C for about 10 hours. This generally leads to about 28g of soot accumulating. Once this has been done, and the amount accumulated verified by weighing, the balance point test can be run.

For this, the engine is run at a constant speed of 3000rpm, and the exhaust gas temperature increased steadily, by increasing the torque. This is done in 20 deg.C steps from 200 to 300 deg.C, and then in steps of 10 deg.C until well past the balance point temperature.

Test Results

Impact Of Balance Point Step Length
Most of the testing at Lubrizol was done with 20 minute balance points. These are useful, because they enable additional studies such as emissions to be made. However, a number of other laboratories run shorter step lengths sch as 5 minutes. The impact of this step length change, on measured balance



* - run on Pt exposed engine

Figure 6

point temperature, was tested using different fuels. The results in Figure 6 show that whilst there is a reduction in the stated temperature for the balance point, using the 20 minute steps, it is the same for all fuels, so the relative ranking remains the same.

The lower balance point is thought to arise from the greater amount of time available for regeneration reactions to get going, and also the increased amount of soot accumulated in the earlier steps leading to a greater reactant concentration on the filter.

There had also been a suggestion that changing between Silicon carbide and Cordierite substrates could influence balance point performances, and indeed favour certain regeneration technologies. In this respect, various fuel additives have been tested in both substrates. The results are shown in figure 7 and

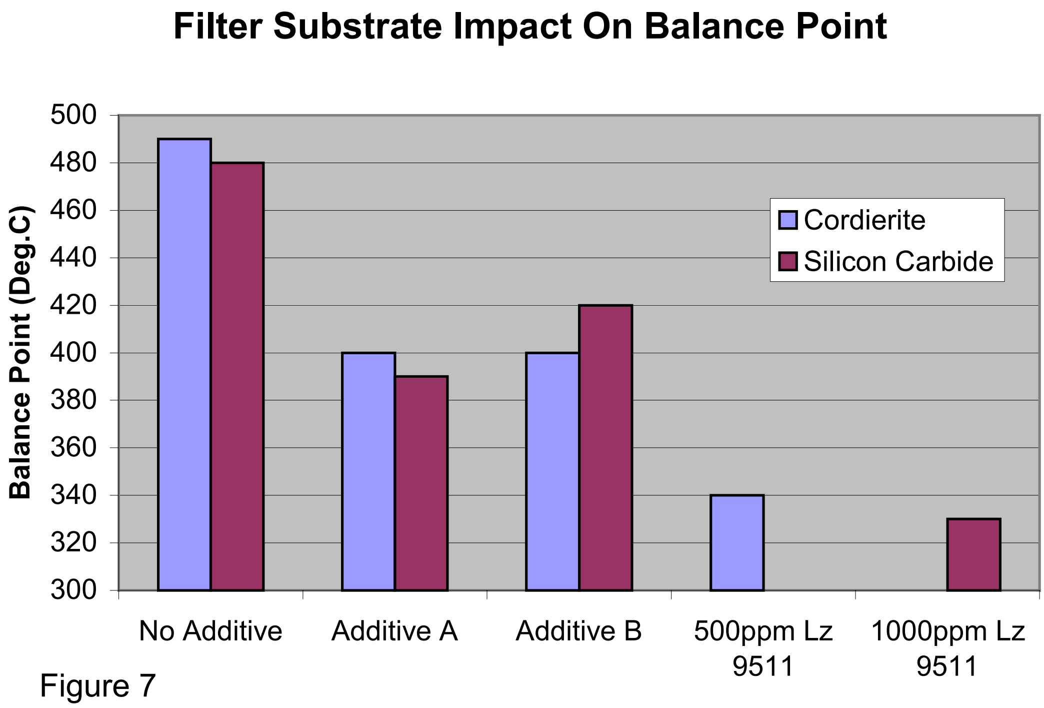
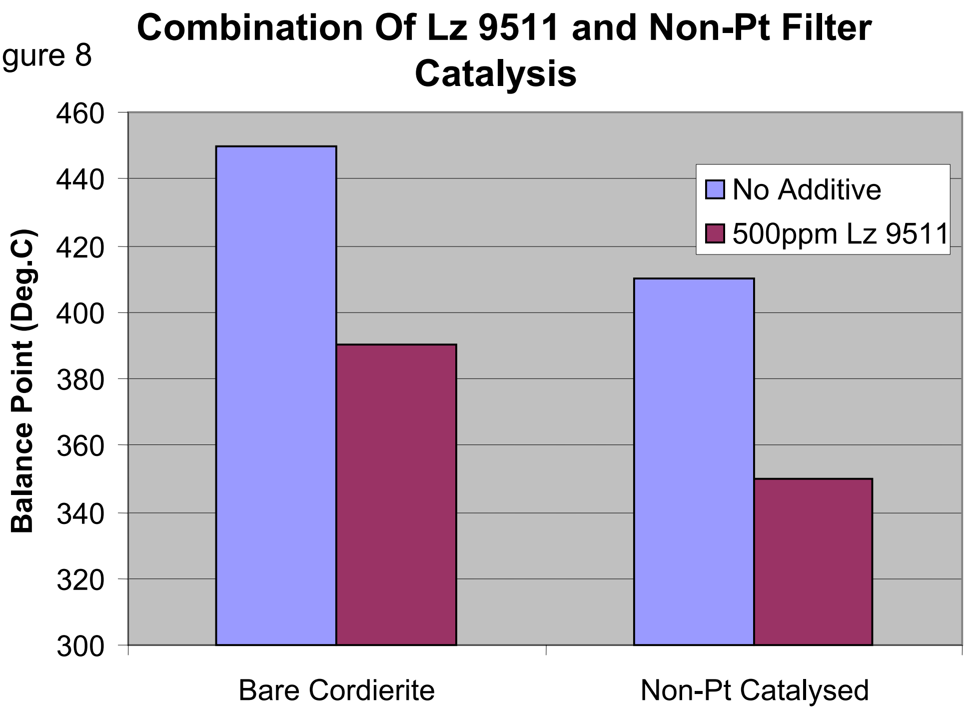


Figure 7

clearly show that changing between these 2 substrates has not significantly impacted balance point performance for the tested technologies either in absolute or relative terms.

Another interesting possibility is whether or not combining passive regeneration technologies can deliver improved particulate filter regeneration

Figure 8



over either technology individually. Lubrizol 9511 (Platinum Cerium based fuel additive) has been combined with a non-Platinum catalysed filter to test precisely this. The results in figure 8 do suggest a significant improvement in balance point over either technology individually, though we would recommend that this is investigated further for verification.

During this work, a couple of interesting points emerged from the data shown in Figure 9. Here, we plot the back pressure at the start of each test, at the

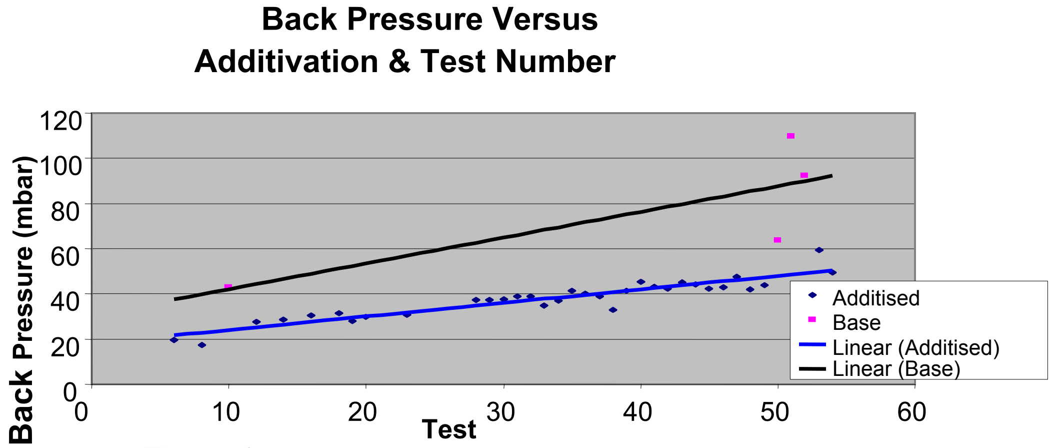


Figure 9

end of the preparation run.. This is at a time when the filter should have been purged of soot by the 600 deg.C temperatures. Clearly, there is a long term increase in back pressure, assumed to be due to ash accumulation. Interestingly, the base fuel results stand out as not following the long term trend, but are much higher and irregular. This is thought to derive from slower soot burnoff (600 deg.C is not much above the temperature at which soot burns uncatalysed), and the fact that the high speed high load conditions used to achieve 600 deg.C actually lead to high levels of engine out soot generation as well, so with these fuels, the filters do not appear totally clean.

Impact Of Pt Based Additives On Other Exhaust Emissions
One of the most interesting aspects of Platinum based additives used with particulate filters is their ability to remove other gaseous emissions without creating harmful secondary emissions. This was well demonstrated in secondary emissions testing for VERT certification.

One aspect of concern with particulate filters is the tendency of some regeneration technologies to increase NO2 emissions. Figure 10 suggests this is not a problem with Platinum based additives, as Lubrizol 9511 does not show a significant increase either before or after conditioning. This is illustrated both with a bare cordierite filter and a non-Platinum catalysed filter. Interestingly, there seems to be some reduction in NO2, with the non-Platinum catalysed filter technology.

Figure 11 shows the same set of filter technologies, but this time, their impact on Carbon Monoxide emissions. The bare cordierite results in these tests are slightly unusual, in that the Carbon Monoxide is seen to reduce across the filter, even when there is no additive. More common is the pattern shown with the non-Platinum catalysed filter: increased carbon Monoxide across the filter when no additive is used. Initial usage of the Platinum based additive

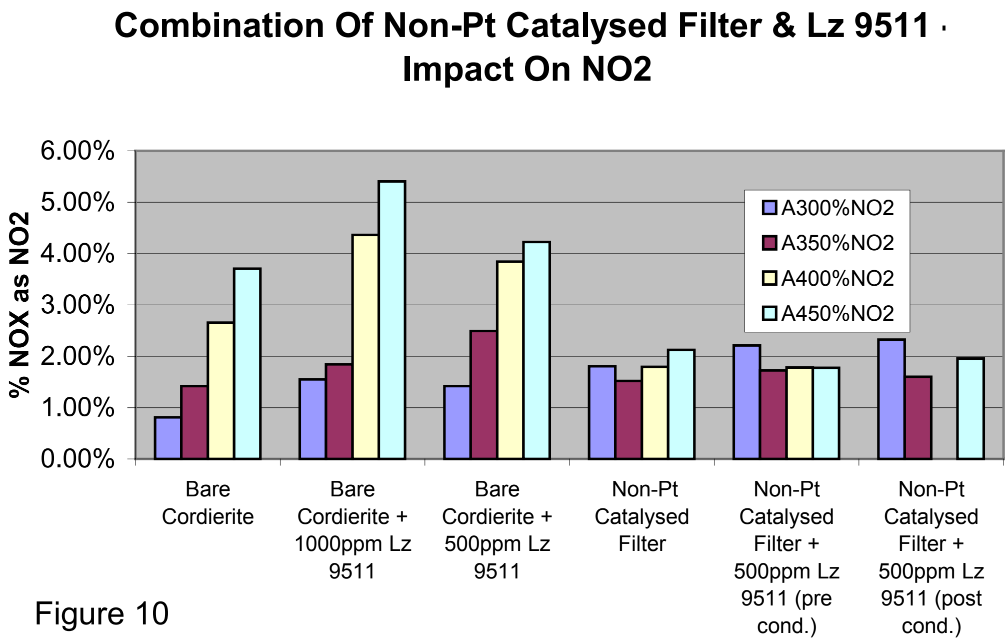


Figure 10

reducing both engine out carbon Monoxide and the subsequent increase

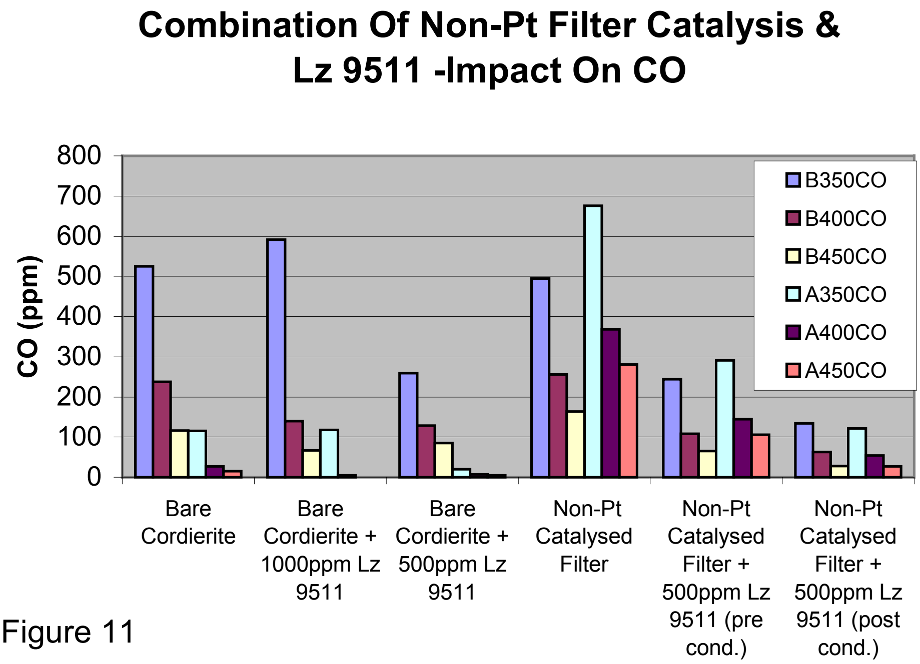


Figure 11

across the filter and further reductions in both as conditioning takes effect.

Work has also been done using the OM 364LA engine. This is widely used in engine oil testing, and more representative of heavy duty diesel engine types. Figure 12 shows the test cell layout used, and Figure 13 shows more precisely where the measurements are taken.

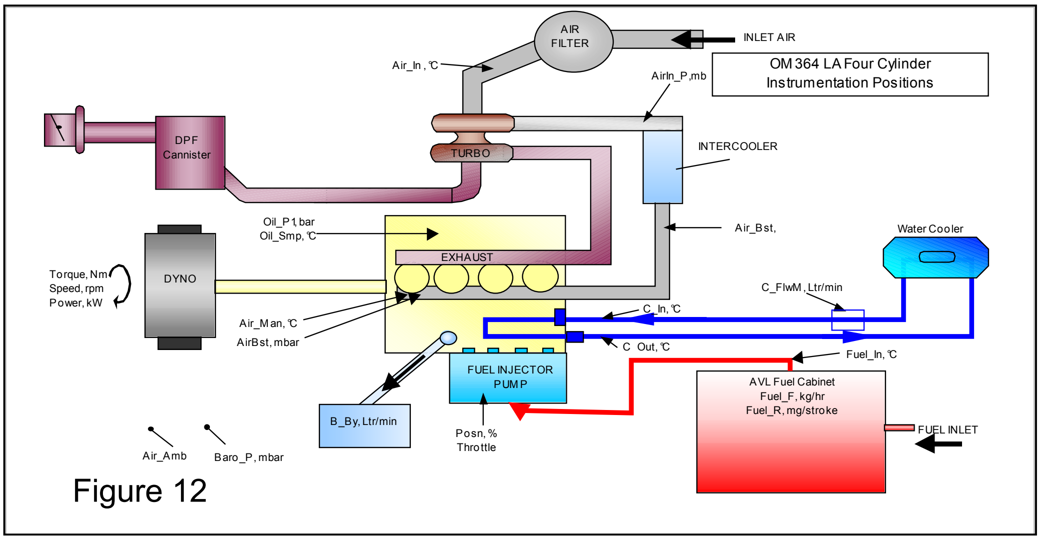


Figure 12

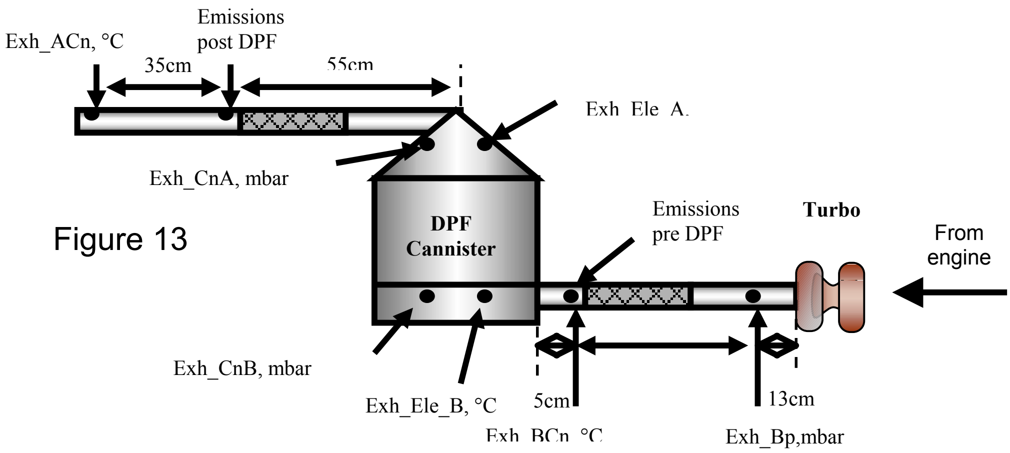
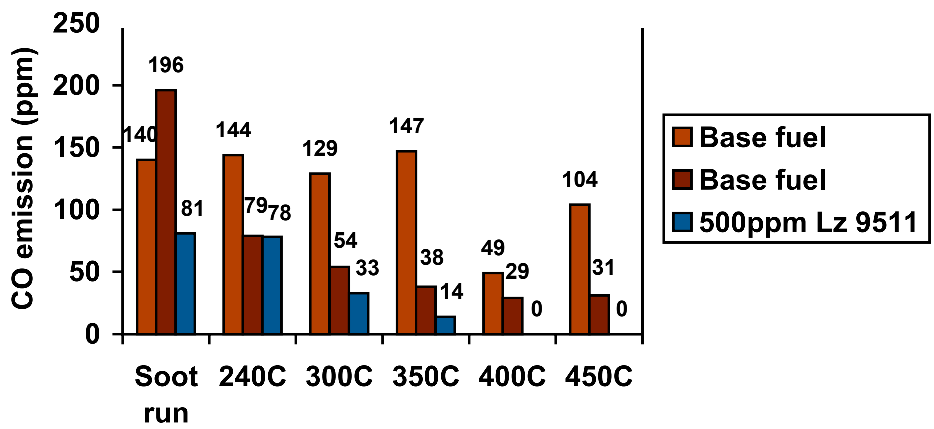


Figure 13

Figure 14 - OM364LA – Engine-out CO Emissions Un-conditioned engine -Filter 1



Using this test setup, the impact on gaseous emissions was examined. As in the VW TDi, CO emissions were controlled engine out. This is shown in Figure 14. On the same engine using another filter, similar behaviour is observed in Figure 15, with the engine out Carbon Monoxide being reduced across the temperature range.

Figure 16 shows initial conditioning effects. Engine out CO emissions are

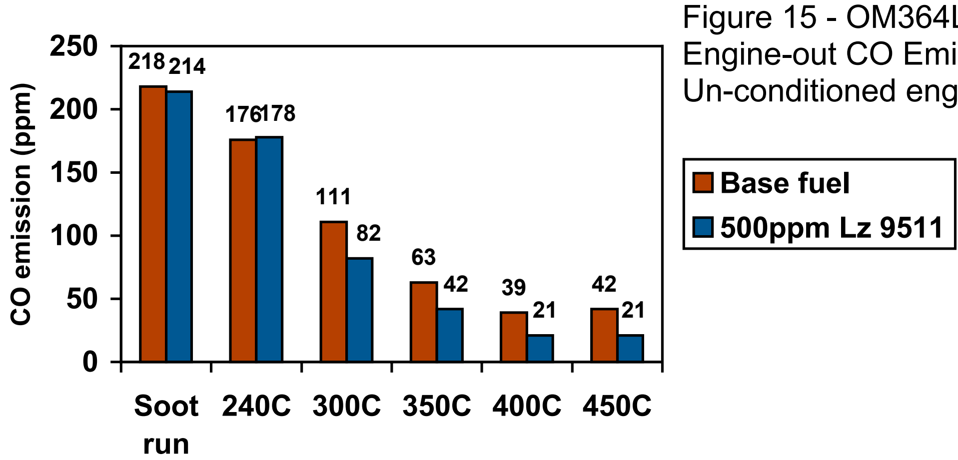


Figure 15 - OM364LA – Engine-out CO Emissions Un-conditioned engine

measured on base fuel, with some Platinum/Cerium additive, during conditioning (x20 treat rate) and after conditioning with the same additive. A

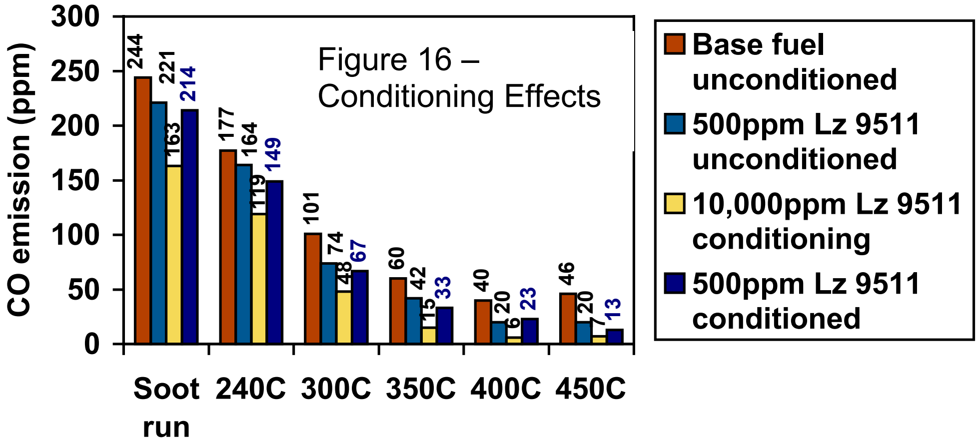


Figure 16 – Conditioning Effects

small conditioning effect is observed, not as large as seen in previous work over a longer term however.

Fuel Consumption Impact

13 mode fuel consumption testing was run on the OM 364LA. Figure 17 shows the results obtained. The results are shown in the following order:

- Base diesel
- After a balance point test with Lubrizol 9511 at 500ppm (this delivers 4ppm metal into the fuel)
- Just prior to a conditioning run, with 80ppm metal in the fuel
- As above but after the conditioning run has been done
- Changing back to 4ppm metal in the fuel, at the start of the test
- As above but after a balance point test has been run
- At the start of a run using a non-Platinum based additive

- At the end of a run using the same non-Platinum based additive.

Whilst the average fuel economy improvement across the usage and conditioning of the Lubrizol 9511 is about 1.9%, this is distorted by an outlier

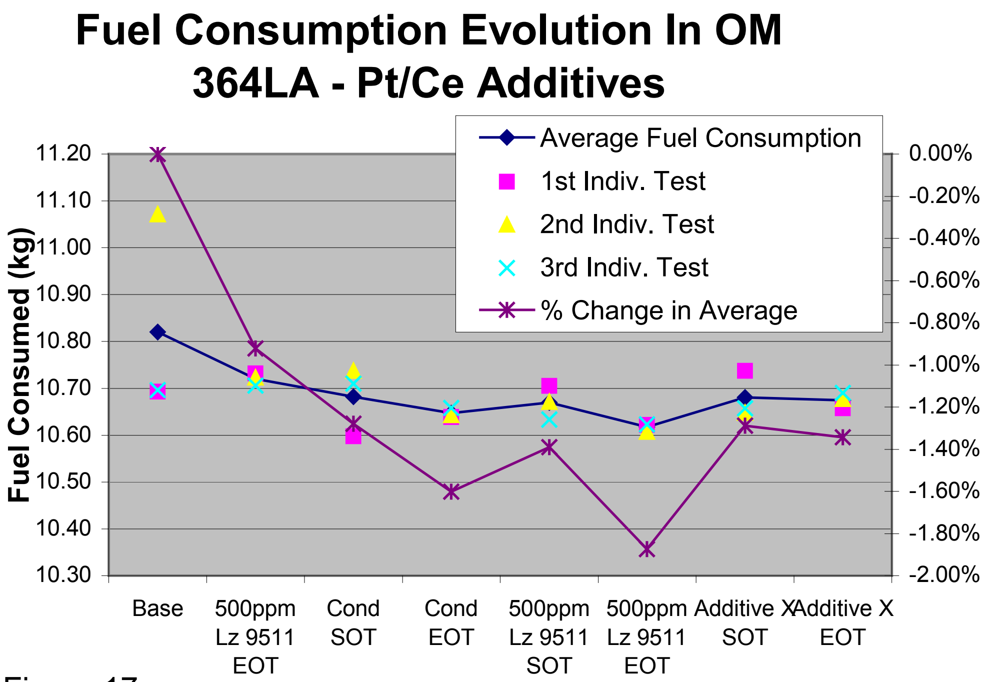


Figure 17

in the initial set of tests on the base fuel. Without this outlier, the improvement seen is closer to 0.9%. Some reversion to higher fuel consumption is seen once the Platinum is taken out. This study was well controlled and thus able to show comparatively small differences in fuel consumption. The fuel consumption benefits seen here are smaller than those reported in some previous studies. This may be due to the shorter conditioning period used in this study.

Conclusions

To summarise what we have show today then:

- Pt based additives used with diesel particulate filters can deliver a useful balance of desirable gaseous emissions oxidation whilst avoiding undesirable reactions such as NO2 increases.
- Benefits can increase with usage (conditioning).
- Technology combinations can further push the envelope.
- Possible fuel economy benefit (0.9%) with short term conditioning, but needs longer term study.