

Test Report



CLIENT CONFIDENTIAL

Client Tesco Stores Ltd

Vehicle Various

Test Momentum 99 FE Trial

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Executive Summary

This report details a series of fuel consumption tests on a range of vehicles to demonstrate the potential fuel consumption and performance benefits of Tesco Momentum 99 fuel.

Four different fuels were tested in this programme: a competitor's forecourt standard 95RON gasoline (Fuel A), Tesco's forecourt standard 95RON gasoline (Fuel B), Tesco's "Momentum 99" premium 99RON gasoline (Fuel C) and a competitor's premium 99RON gasoline (Fuel D). Before exhaust emissions testing took place on the vehicles, they were first conditioned to each fuel, which involved a fuel and oil flush procedure before running 1000 miles of mileage accumulation on Millbrook's tracks.

Each vehicle was then tested over three separate drive cycles. First, a cold start European legislated NEDC was completed, immediately followed by a hot start American US06 drive cycle. Each vehicle was then left to soak overnight and following this, a cold start Federal legislated EPAIII was performed. A total of three emissions tests were undertaken on each drive cycle to allow repeatability criteria to be calculated. Therefore, each vehicle performed nine emissions tests using each test fuel.

Once the emissions tests were complete on each fuel, the vehicles were subjected to track based testing by an external contractor hired by Tesco Stores. These tests attributed to additional mileage on each vehicle between emissions testing and the mileage accumulation.

Comparing Fuel B to Fuel A, the average fuel consumption over the eight test vehicles changed as follows:

- Over the NEDC drive cycle, the average fuel consumption statistically decreased by 0.01%.
- Over the US06 drive cycle, the average fuel consumption statistically decreased by 3.04%.
- Over the EPAIII drive cycle, the average fuel consumption statistically increased by 0.005%.

Comparing Fuel C to Fuel B, the average fuel consumption over the eight test vehicles changed as follows:

- Over the NEDC drive cycle, the average fuel consumption statistically decreased by 2.96%.
- Over the US06 drive cycle, the average fuel consumption statistically decreased by 3.80%.

- Over the EPAIII drive cycle, the average fuel consumption statistically decreased by 3.05%.

Comparing Fuel D to Fuel C, the average fuel consumption over the eight test vehicles changed as follows:

- Over the NEDC drive cycle, the average fuel consumption statistically decreased by 0.07%.
- Over the US06 drive cycle, the average fuel consumption statistically increased by 1.48%.
- Over the EPAIII drive cycle, the average fuel consumption statistically decreased by 0.16%.

Borescope inspections were performed on the inlet valves and injectors of each vehicle before and after each fuel was tested to analyse the level of carbon deposits present and to allow the clean up properties of each fuel to be evaluated. Images that were captured of the inlet valves and injectors were passed to a qualified rater who measured the degree of carbon deposits present and gave each image a rating based on this.

These inspections were only performed on the four port fuelled vehicles that were tested. The other four direct injection vehicles could not be officially rated as the fuel does not come into direct contact with the inside face of the inlet valve and so any deposits on these types of vehicles could not be attributed to the different fuel types.

The results from these borescope inspections are as follows:

- Following the Fuel A emissions testing, the Fiesta and the Panda showed a slight increase in inlet valve deposits. The 207 and the Scenic showed no change in condition of inlet valves compared with the start of test results.
- Following the Fuel B emissions testing, the Fiesta and the Panda showed a slight decrease in inlet valve deposits. The 207 showed no change in either inlet valve or injector deposits and the Scenic showed an increase in both inlet valve and injector deposits compared with Fuel A results.
- Following the Fuel C emissions testing, the Scenic showed a slight decrease in inlet valve deposits. The other three vehicles showed slightly more fouled results, with the Fiesta and Panda showing an increase in inlet valve deposits and the 207 showing an increase in injector deposits compared with Fuel B results.
- Following the Fuel D emissions testing, the Fiesta, Panda and Scenic showed a decrease in inlet valve deposits with no change in the condition of the injectors. The 207 showed no change in the condition of the valves but a decrease in injector deposits compared with Fuel C results.

Distribution

Organisation	Recipient	Format	Qty
New Tesco House Delamare Road Cheshunt Hertfordshire EN8 9SL	Dr. A. Burrows Mr. J. Burton	PDF	1
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Report Revision History

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Objectives

1. To conduct a suite of 3 cold start NEDC exhaust emission tests on 8 test vehicles on four different fuels.
2. To conduct a suite of 3 hot start US06 exhaust emission tests on 8 test vehicles on four different fuels.
3. To conduct a suite of 3 cold start EPAIII exhaust emission tests on 8 test vehicles on four different fuels.
4. To evaluate the performance of Tesco standard 95RON gasoline against a competitor's forecourt standard 95RON gasoline, including analysis of fuel consumption and valve/injector deposits.
5. To evaluate the performance of Tesco 'Momentum 99' premium 99RON gasoline against Tesco standard 95RON gasoline, including analysis of fuel consumption and valve/injector deposits.
6. To evaluate the performance of Tesco 'Momentum 99' premium 99RON gasoline against a competitor's premium 99RON gasoline, including analysis of fuel consumption and valve/injector deposits.

Conclusions

1. Tests were carried out on the 8 test vehicles using four different fuels. Exhaust emissions were measured using a comprehensive range of instrumentation to establish regulated emission levels over the NEDC drive cycle. Furthermore, CO₂ emissions were measured over the cycle and fuel consumption was calculated using the regulatory carbon balance method.
2. Tests were carried out on the 8 test vehicles using four different fuels. Exhaust emissions were measured using a comprehensive range of instrumentation to establish regulated emission levels over the US06 drive cycle. Furthermore, CO₂ emissions were measured over the cycle and fuel consumption was calculated using the regulatory carbon balance method.
3. Tests were carried out on the 8 test vehicles using four different fuels. Exhaust emissions were measured using a comprehensive range of instrumentation to establish regulated emission levels over the EPAIII drive cycle. Furthermore, CO₂ emissions were measured over the cycle and fuel consumption was calculated using the regulatory carbon balance method.
4. The fuel consumption results and borescope inspections from Tesco's standard 95RON gasoline (Fuel B) were compared with the results from a competitor's standard forecourt 95RON gasoline (Fuel A). The following results were concluded:

- Over the NEDC drive cycle, the average fuel consumption statistically decreased 0.01% using Fuel B on the 8 test vehicles compared with Fuel A.
 - Over the US06 drive cycle, the average fuel consumption statistically decreased 3.04% using Fuel B on the 8 test vehicles compared with Fuel A.
 - Over the EPAIII drive cycle, the average fuel consumption statistically increased by 0.005% using Fuel B on the 8 test vehicles compared with Fuel A.
 - The borescope inspections showed that the Fiesta and the Panda exhibited a slight decrease in inlet valve deposits, the 207 exhibited no significant change in inlet valve or injector deposits and the Scenic exhibited an increase in both inlet valve and injector deposits compared with Fuel A.
5. The fuel consumption results and borescope inspections from Tesco 'Momentum 99' premium 99RON gasoline (Fuel C) were compared with the results from Tesco's standard 95RON gasoline (Fuel B). The following results were concluded:
- Over the NEDC drive cycle, the average fuel consumption statistically decreased 2.96% using Fuel C on the 8 test vehicles compared with Fuel B.
 - Over the US06 drive cycle, the average fuel consumption statistically decreased 3.80% using Fuel C on the 8 test vehicles compared with Fuel B.
 - Over the EPAIII drive cycle, the average fuel consumption statistically decreased 3.05% using Fuel C on the 8 test vehicles compared with Fuel B.
 - The borescope inspections showed that the Scenic exhibited a slight decrease in inlet valve deposits. The other three vehicles exhibited slightly more fouled results, with the Fiesta and Panda showing an increase in inlet valve deposits and the 207 showing an increase in injector deposits compared with Fuel B results.
6. The fuel consumption results and borescope inspections from competitor's premium 99RON gasoline (Fuel D) were compared with the results from Tesco 'Momentum 99' premium 99RON gasoline (Fuel C). The following results were concluded:
- Over the NEDC drive cycle, the average fuel consumption statistically decreased 0.07% using Fuel D on the 8 test vehicles compared with Fuel C.

- Over the US06 drive cycle, the average fuel consumption statistically increased 1.48% using Fuel D on the 8 test vehicles compared with Fuel C.
- Over the EPAIII drive cycle, the average fuel consumption statistically decreased 0.16% using Fuel D on the 8 test vehicles compared with Fuel C.
- The borescope inspections showed the Fiesta, Panda and Scenic exhibited a decrease in inlet valve deposits with no change in injector deposits, while the 207 exhibited a decrease in injector deposits and no significant change in inlet valve conditions compared the Fuel C.

Test Facility and Date

The tests were performed between the 23rd January 2012 and 4th May 2012 in the Vehicle Emissions Laboratory (VEL) test facility at Millbrook Proving Ground Ltd.

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Vehicle Specifications

Vehicle 1 – Peugeot 207

Registration Number	CX58 VUT
Chassis Number	VF3WE8FSC34475362
Vehicle OEM and Model	207 S SW WE8FSC
Engine OEM & Model	FGAH0339805
Transmission OEM & Model	5-Speed Manual
Power Rating	70 kW @ 6,000 RPM
Torque Rating	136 Nm @ 4,000 RPM
Engine Size	1397 cc, 4 cylinder
Euro Standard	Euro 5
Start of Test Mileage	20,832 miles

Vehicle 2 – Ford Fiesta

Registration Number	LL11 RUA
Chassis Number	WF0JXXWPJJBL80368
Vehicle OEM and Model	Fiesta Zetec JA8 SPJC1J
Engine OEM & Model	BL80368
Transmission OEM & Model	5-Speed Manual
Power Rating	71 kW @ 5,650 RPM
Torque Rating	125 Nm @ 4,050 RPM
Engine Size	1388 cc, 4 cylinder
Euro Standard	Euro 5
Start of Test Mileage	15,572 miles

Vehicle 3 – Fiat Panda

Registration Number	CX58 WGP
Chassis Number	ZFA16900001231155
Vehicle OEM and Model	Panda Eleganza AXB1A 01C
Engine OEM & Model	4589012
Transmission OEM & Model	5-Speed Manual
Power Rating	44 kW @ 5,000 RPM
Torque Rating	102 Nm @ 2,500 RPM
Engine Size	1242 cc, 4 cylinder
Euro Standard	Euro 4
Start of Test Mileage	20,218 miles

Vehicle 4 – Volkswagen Golf TSi

Registration Number	RE08 VMK
Chassis Number	WVWZZZ1KZ8W254601
Vehicle OEM and Model	Golf Match TSi ACCAXAX0
Engine OEM & Model	CAX 036972
Transmission OEM & Model	5-Speed Manual
Power Rating	103 kW @ 5,600 RPM
Torque Rating	220 Nm @ 1,750 RPM
Engine Size	1390 cc, 4 cylinder
Euro Standard	Euro 5
Start of Test Mileage	76,397 miles

Vehicle 5 – Renault Grand Scenic

Registration Number	MK59 XRW
Chassis Number	VF1JZ0VB641925175
Vehicle OEM and Model	Grand Scenic Dyn VVT JZ0VB6
Engine OEM & Model	D031342
Transmission OEM & Model	6-Speed Manual
Power Rating	81 kW @ 6,000 RPM
Torque Rating	150 Nm @ 4,250 RPM
Engine Size	1598 cc, 4 cylinder
Euro Standard	Euro 5
Start of Test Mileage	20,581 miles

Vehicle 6 – Volkswagen Golf FSi

Registration Number	HY55 WSW
Chassis Number	WVWZZZ1KZ6W032332
Vehicle OEM and Model	Golf SE Auto ABBLFX0
Engine OEM & Model	BLF 196220
Transmission OEM & Model	6-Speed Auto
Power Rating	84 kW @ 6,000 RPM
Torque Rating	155 Nm @ 4,000 RPM
Engine Size	1600 cc, 4 cylinder
Euro Standard	Euro 4
Start of Test Mileage	61,166 miles

Vehicle 7 – BMW 325i

Registration Number	WJ09 KXX
Chassis Number	WBAVE32040A145278
Vehicle OEM and Model	325i M Sport Auto VE32
Engine OEM & Model	77404325
Transmission OEM & Model	6-speed Auto
Power Rating	163 kW @ 6,100 RPM
Torque Rating	270 Nm @ 2,400 - 4,200 RPM
Engine Size	2996 cc, 4 cylinder
Euro Standard	Euro 4
Start of Test Mileage	21,369 miles

Vehicle 8 – Audi TT

Registration Number	KR58 ZTH
Chassis Number	TRUZZZ8J691011273
Vehicle OEM and Model	TT TFSI RBWAF1
Engine OEM & Model	BWA 249740
Transmission OEM & Model	6-Speed Manual
Power Rating	147 kW @ 5,100 - 6,000 RPM
Torque Rating	280 Nm @ 1,800 - 5,000 RPM
Engine Size	1984 cc, 4 cylinder
Euro Standard	Euro 5
Start of Test Mileage	42,567 miles

Fuel Specifications

Tesco supplied four fuels for testing during this programme. Each of these fuels were analysed by a third party and details of fuel density and carbon weight fraction were provided for calculation of the fuel consumption. The fuel specifications were as follows:

- Fuel A – a competitor's forecourt standard 95RON gasoline
 - Carbon Weight Fraction = 0.8463
 - Fuel Density = 0.7298 g/mL
- Fuel B – Tesco's forecourt standard 95RON gasoline
 - Carbon Weight Fraction = 0.8467
 - Fuel Density = 0.7305 g/mL
- Fuel C – Tesco's 'Momentum 99' premium 99RON gasoline
 - Carbon Weight Fraction = 0.8559
 - Fuel Density = 0.7543 g/mL
- Fuel D – a competitor's premium 99RON gasoline
 - Carbon Weight Fraction = 0.8554
 - Fuel Density = 0.7481 g/mL

Test Procedure

Prior to the vehicles being filled with test fuel, any vehicles with port fuelled engines had boroscope inspections of the inlet valve and injector deposits. A qualified rater then examined the images and rated them based on the level of deposits. This inspection was performed before and after each fuel was tested to assess any clean up effects due to each fuel.

Each of the 8 vehicles was then filled with Fuel A, using the following procedure:

- Drain all fuel and oil
- Change fuel filter and oil filter
- Fill with 15L test fuel and fill oil to maximum mark
- Drive on chassis dynamometer over NEDC drive cycle
- Drain all fuel and oil
- Change fuel filter and oil filter
- Fill with test fuel to max and fill oil to max

This procedure was put in place to ensure that the oil remained in the same condition prior to each fuel test and to ensure that there were no carry over effects occurring from one fuel to the next due to the condition of the oil.

Once the fuel/oil change procedure was completed, each vehicle undertook 1000 miles of mileage accumulation on Millbrook's test tracks to condition each vehicle to the test fuel. A specialised 'Public Road Simulation' (PRS) procedure was used to accumulate the required mileage, as outlined in Section 6.1.

Before testing, the vehicles were assigned a set of dyno tyres that were used exclusively for emissions testing. This action was performed to eliminate any variability caused by the deterioration of the tyre during the vehicles mileage accumulation. Furthermore, tyre pressures were checked and reset as necessary before and after each emissions test to ensure a consistent surface area of the tyres were in contact with the dyno rollers for all tests.

The road load models for each vehicle were generated using information collected about each vehicle mass and the appropriate 'cookbook' loads were selected for use on the chassis dynamometer.

Regulated exhaust emission levels were established over the European legislated NEDC (New European Drive Cycle – cold start), immediately followed by the American US06 drive cycle (hot start). Following this, the vehicles were soaked again to allow a cold start EPAIII drive cycle to be performed. A total of three emissions tests were undertaken on each cycle to allow repeatability criteria to be calculated. To aid repeatability, the same driver was used in each vehicle through the length of the programme.

Emissions analysis included measurements of THC, CO, NO_x and CO₂ emissions using the European legislated CVS methodology. Fuel consumption was calculated using the regulatory carbon balance method. In addition to the legislated 'bag' pollutants, second-by-second modal gaseous emissions were also measured at the tailpipe. Tests were carried out at the standard homologation test temperature, which was kept as constant as possible throughout the fuels matrix.

Following Millbrook's emissions testing on each test fuel, the vehicles were passed to an external contractor hired by Tesco Stores where they were subjected to track based testing. These tests attributed to additional mileage on each vehicle between emissions testing and the mileage accumulation.

Once the baseline tests were completed on Fuel A, the aforementioned fuel/oil change procedure was performed on each test vehicle once again, using Fuel B in place of Fuel A. The mileage accumulation and exhaust emissions test procedure was then completed for Fuel B on all vehicles. This entire process was repeated again for Fuel C and Fuel D, ending in a total of 36 test results on each vehicle (9 tests using each fuel, consisting of 3 tests on each of the 3 drive cycles).

However, before vehicles were tested on Fuel D, the test vehicles were first flushed with Fuel B (using the fuel/oil change procedure) and completed an extra 1000 miles conditioning with this fuel before Fuel D's fuel/oil change procedure. This action was performed to ensure the vehicles tested on Fuel D would have the same starting conditions as Fuel C and hence any carry over effects from Fuel C to Fuel D were minimised.

Public Road Simulation (PRS)

It is not Millbrook's policy to run test vehicles on the public roads due to safety, test repeatability and control criteria. We have developed a 'Public Road Simulation' (PRS) package which is a repeatable test procedure run safely on Millbrook's test tracks in a secure environment. The procedure is made from several different selected modules giving the required running simulation of various road types.

Millbrook's test tracks are specifically designed to replicate the public road. It is for this reason that true vehicle conditioning and representative mileage accumulation can be conducted under repeatable and controlled conditions. This includes all aspects of driving such as high speed motorway, city simulation and hills.

Conditioning Cycle

PRS profile breakdown for mileage conditioning equivalent to approximately 3 full tanks of fuel based upon an average fuel tank capacity of 60 litres and using an average fuel consumption of 10 litres per 100km: giving a target distance travelled of 1800km/1000 miles.

MODULE	DESCRIPTION	DISTANCE (km)	REPEATS	TOTAL DISTANCE (km)	% OF TOTAL
MODULE 1	UK Motorway	12.872	35	451	25%
MODULE 2	A' & 'B' Roads	14.25	70	998	56%
MODULE 6	Urban	6.275	39	245	14%
MODULE 7	Mountain road	4.5	22	99	6%
Total		37.897	166	1792	100%

Instrumentation

	Pollutant	Measurement technique	Frequency	Analysis technique
Regulated	Total hydrocarbons (HC)	Continuously integrated	Per phase	Flame ionisation
	Carbon monoxide (CO)	Bag	Per phase	Non-dispersive IR
	Nitrogen oxides (NOx)	Bag	Per phase	Chemiluminescence
Unregulated	Carbon dioxide (CO ₂)	Bag	Per phase	Non-dispersive IR
	Total hydrocarbons (HC)	Continuous modal tailpipe and engine	1 Hz	Flame Ionization
	Carbon monoxide (CO)	Continuous modal tailpipe and engine	1 Hz	Non-dispersive IR
	Nitrogen oxides (NOx)	Continuous modal tailpipe and engine	1 Hz	Chemiluminescence
	Carbon dioxide (CO ₂)	Continuous modal tailpipe and engine	1 Hz	Non-dispersive IR

Test Results and Discussion

When running fuel economy test programmes, Millbrook has an acceptable tolerance of 2% variability in CO₂ for a single set of tests.

The variance of CO₂ over the duration of testing typically ranged from 0.1% to 1.0%, which was well below the 2% limit. This meets Millbrook's repeatability requirements and therefore allows a high degree of confidence in the precision of the results obtained.

Furthermore, using the "Two Sample t-Test for Independent Samples", a statistical model used to evaluate the significance between two independent samples of data, the statistical significance of the results was calculated. More information about this model can be found in *Appendix A*.

Cold Start NEDC Testing

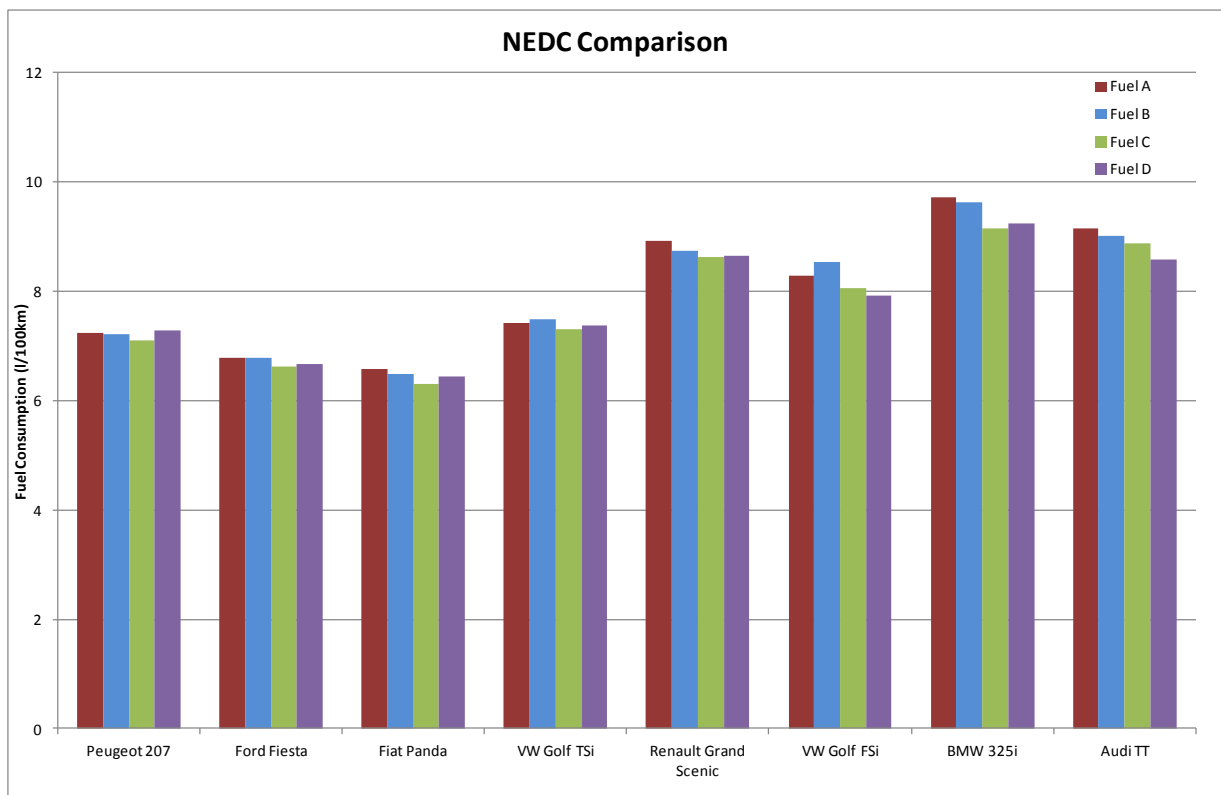


Figure 1 - NEDC Comparison

Figure 1 shows the fuel consumption results of the 8 vehicles on the four test fuels over the NEDC drive cycle. Each vehicle's results show the following:

1. Peugeot 207:
 - On Fuel A, the Peugeot 207 showed a fuel consumption of 7.239 l/100km.

- Using Fuel B, the 207 showed a fuel consumption of 7.205 l/100km, a decrease of 0.46% on Fuel A. However, this result was not statistically significant.
 - Using Fuel C, the 207 showed a fuel consumption of 7.090 l/100km, a statistically significant decrease of 1.60% on Fuel B.
 - Using Fuel D, the 207 showed a fuel consumption of 7.284 l/100km, a statistically significant increase of 2.73% on Fuel C.
2. Ford Fiesta:
- On Fuel A, the Ford Fiesta showed a fuel consumption of 6.784 l/100km.
 - Using Fuel B, the Fiesta showed a fuel consumption of 6.785 l/100km, an increase of 0.01% on Fuel A. However, this result was not statistically significant.
 - Using Fuel C, the Fiesta showed a fuel consumption of 6.628, a statistically significant decrease of 2.31% on Fuel B.
 - Using Fuel D, the Fiesta showed a fuel consumption of 6.668 l/100km, an increase of 0.59% on Fuel C. This result was not statistically significant.
3. Fiat Panda:
- On Fuel A, the Fiat Panda showed a fuel consumption of 6.568 l/100km.
 - Using Fuel B, the Panda showed a fuel consumption of 6.496 l/100km, a decrease of 1.10% on Fuel A. This result was not statistically significant.
 - Using Fuel C, the Panda showed a fuel consumption of 6.313 l/100km, a statistically significant decrease of 2.82% on Fuel B.
 - Using Fuel D, the Panda showed a fuel consumption of 6.438 l/100km, a statistically significant increase of 1.99% on Fuel C.
4. Volkswagen Golf TSi:
- On Fuel A, the Volkswagen Golf TSi showed a fuel consumption of 7.428 l/100km on Fuel A.
 - Using Fuel B, the TSi Golf showed a fuel consumption of 7.480 l/100km, a statistically significant increase of 0.70% on Fuel A.
 - Using Fuel C, the TSi Golf showed a fuel consumption of 7.311 l/100km, a statistically significant decrease of 2.26% on Fuel B.
 - Using Fuel D, the TSi Golf showed a fuel consumption of 7.380 l/100km, an increase of 0.95% on Fuel C. However, this result was not statistically significant.
5. Renault Grand Scenic:
- On Fuel A, the Renault Grand Scenic showed a fuel consumption of 8.931 l/100km.
 - Using Fuel B, the Scenic showed a fuel consumption of 8.747 l/100km, a statistically significant decrease of 2.06% on Fuel A.
 - Using Fuel C, the Scenic showed a fuel consumption of 8.632 l/100km, a decrease of 1.32% on Fuel B. However, this result was not statistically significant.
 - Using Fuel D, the Scenic showed a fuel consumption of 8.648 l/100km, an increase of 0.19% on Fuel C. This result was also not statistically significant.

6. Volkswagen Golf FSi:

- On Fuel A, the Volkswagen Golf FSi showed a fuel consumption of 8.286 l/100km.
- Using Fuel B, the FSi Golf showed a fuel consumption of 8.526 l/100km, a statistically significant increase of 2.90% on Fuel A.
- Using Fuel C, the FSi Golf showed a fuel consumption of 8.052 l/100km, a statistically significant decrease of 5.57% on Fuel B.
- Using Fuel D, the FSi Golf showed a fuel consumption of 7.919 l/100km, a statistically significant decrease of 1.64% on Fuel C.

7. BMW 325i:

- On Fuel A, the BMW 325i showed a fuel consumption of 9.727 l/100km.
- Using Fuel B, the 325i showed a fuel consumption of 9.626 l/100km, a decrease of 1.04% on Fuel A. However, this result was not statistically significant.
- Using Fuel C, the 325i showed a fuel consumption of 9.160 l/100km, a statistically significant decrease of 4.84% on Fuel B.
- Using Fuel D, the 325i showed a fuel consumption of 9.246 l/100km, an increase of 0.94% on Fuel C. This result was not statistically significant.

8. Audi TT:

- On Fuel A, the Audi TT showed a fuel consumption of 9.148 l/100km.
- Using Fuel B, the TT showed a fuel consumption of 9.005 l/100km, a statistically significant decrease of 1.57% on Fuel A.
- Using Fuel C, the TT showed a fuel consumption of 8.884 l/100km, a statistically significant decrease of 1.34% on Fuel B.
- Using Fuel D, the TT showed a fuel consumption of 8.587 l/100km, a statistically significant decrease of 3.35% on Fuel C

On average, over all 8 of the test vehicles on the NEDC drive cycle, Fuel B decreased fuel consumption by 0.33% compared to Fuel A. If only the statistically significant figures are considered, then the fuel consumption decreased by 0.01% compared to Fuel A.

Furthermore, Fuel C decreased the average fuel consumption over the 8 test vehicles by 2.76% compared to Fuel B. Considering only the statistically significant figures, then Fuel C decreased fuel consumption by 2.96% compared with Fuel B.

Finally, Fuel D increased the average fuel consumption over the 8 test vehicles by 0.30% compared to Fuel C. Considering only statistically significant figures, then Fuel D decreased the average fuel consumption by 0.07% compared with Fuel C.

Hot Start US06 Testing

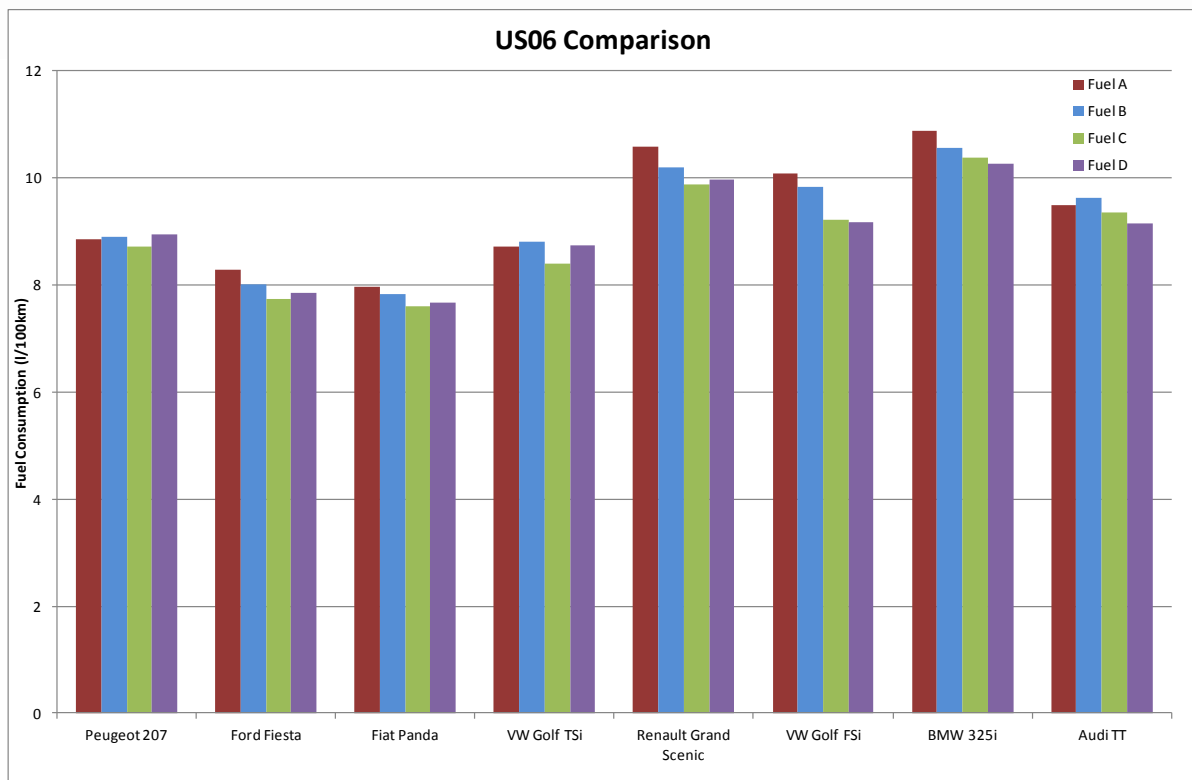


Figure 2 - US06 Comparison

Figure 2 shows the fuel consumption results of the 8 vehicles on the four test fuels over the US06 drive cycle. Each vehicle's results show the following:

1. Peugeot 207:
 - On Fuel A, the Peugeot 207 showed a fuel consumption of 8.855 l/100km.
 - Using Fuel B, the 207 showed a fuel consumption of 8.904 l/100km, an increase of 0.56% on Fuel A. However, this result was not statistically significant.
 - Using Fuel C, the 207 showed a fuel consumption of 8.710 l/100km, a decrease of 2.17% on Fuel B. This result was also not statistically significant.
 - Using Fuel D, the 207 showed a fuel consumption of 8.945 l/100km, a statistically significant increase of 2.69% on Fuel C.
2. Ford Fiesta:
 - On Fuel A, the Ford Fiesta showed a fuel consumption of 8.276 l/100km.
 - Using Fuel B, the Fiesta showed a fuel consumption of 8.007 l/100km, a statistically significant decrease of 3.25% on Fuel A.
 - Using Fuel C, the Fiesta showed a fuel consumption of 7.744 l/100km, a statistically significant decrease of 3.28% on Fuel B.
 - Using Fuel D, the Fiesta showed a fuel consumption of 7.848 l/100km, an increase of 1.35% on Fuel C. However, this result was not statistically significant.

3. Fiat Panda:

- On Fuel A, the Fiat Panda showed a fuel consumption of 7.971 l/100km.
- Using Fuel B, the Panda showed a fuel consumption of 7.820 l/100km, a decrease of 1.89% on Fuel A. This result was not statistically significant.
- Using Fuel C, the Panda showed a fuel consumption of 7.593 l/100km, a statistically significant decrease of 2.90% on Fuel B.
- Using Fuel D, the Panda showed a fuel consumption of 7.666 l/100km, an increase of 0.95% on Fuel C. This result was not statistically significant.

4. Volkswagen Golf TSi:

- On Fuel A, the Volkswagen Golf TSi showed a fuel consumption of 8.723 l/100km.
- Using Fuel B, the TSi Golf showed a fuel consumption of 8.819 l/100km, an increase of 1.11% on Fuel A. However, this result was not statistically significant.
- Using Fuel C, the TSi Golf showed a fuel consumption of 8.406 l/100km, a statistically significant decrease of 4.69% on Fuel B.
- Using Fuel D, the TSi Golf showed a fuel consumption of 8.746 l/100km, a statistically significant increase of 4.05% on Fuel C.

5. Renault Grand Scenic:

- On Fuel A, the Renault Grand Scenic showed a fuel consumption of 10.588 l/100km.
- Using Fuel B, the Scenic showed a fuel consumption of 10.193 l/100km, a statistically significant decrease of 3.73% on Fuel A.
- Using Fuel C, the Scenic showed a fuel consumption of 9.886 l/100km, a statistically significant decrease of 3.01% on Fuel B.
- Using Fuel D, the Scenic showed a fuel consumption of 9.971 l/100km, an increase of 0.86% on Fuel C. However, this result was not statistically significant.

6. Volkswagen Golf FSi:

- On Fuel A, the Volkswagen Golf FSi showed a fuel consumption of 10.075 l/100km.
- Using Fuel B, the FSi Golf showed a fuel consumption of 9.839 l/100km, a statistically significant decrease of 2.35% on Fuel A.
- Using Fuel C, the FSi Golf showed a fuel consumption of 9.227 l/100km, a statistically significant decrease of 6.22% on Fuel B.
- Using Fuel D, the FSi Golf showed a fuel consumption of 9.169 l/100km, a decrease of 0.63% on Fuel C. However, this result was not statistically significant.

7. BMW 325i:

- On Fuel A, the BMW 325i showed a fuel consumption of 10.876 l/100km.
- Using Fuel B, the 325i showed a fuel consumption of 10.570 l/100km, a statistically significant decrease of 2.82% on Fuel A.
- Using Fuel C, the 325i showed a fuel consumption of 10.381 l/100km, a decrease of 1.79% on Fuel B. However, this result was not statistically significant.

- Using Fuel D, the 325i showed a fuel consumption of 10.263 l/100km, a decrease of 1.14% on Fuel C. This result was also not statistically significant.
8. Audi TT:
- On Fuel A, the Audi TT showed a fuel consumption of 9.483 l/100km.
 - Using Fuel B, the TT showed a fuel consumption of 9.625 l/100km, an increase of 1.50% on Fuel A. This result was not statistically significant.
 - Using Fuel C, the TT showed a fuel consumption of 9.363 l/100km, a statistically significant decrease of 2.72% on Fuel B.
 - Using Fuel D, the TT showed a fuel consumption of 9.149 l/100km, a statistically significant decrease of 2.28% on Fuel C.

On average, over all 8 of the test vehicles on the US06 drive cycle, Fuel B decreased fuel consumption by 1.36% compared to Fuel A. If only the statistically significant figures are considered, then the fuel consumption decreased by 3.04% compared to Fuel A.

Furthermore, Fuel C decreased the average fuel consumption over the 8 test vehicles by 3.35% compared to Fuel B. Considering only the statistically significant figures, then Fuel C decreased fuel consumption by 3.80% compared with Fuel B.

Finally, Fuel D increased the average fuel consumption over the 8 test vehicles by 0.73% compared to Fuel C. Considering only statistically significant figures, then Fuel D increased the average fuel consumption over the cycle by 1.48% compared with Fuel C.

Cold Start EPAIII Testing

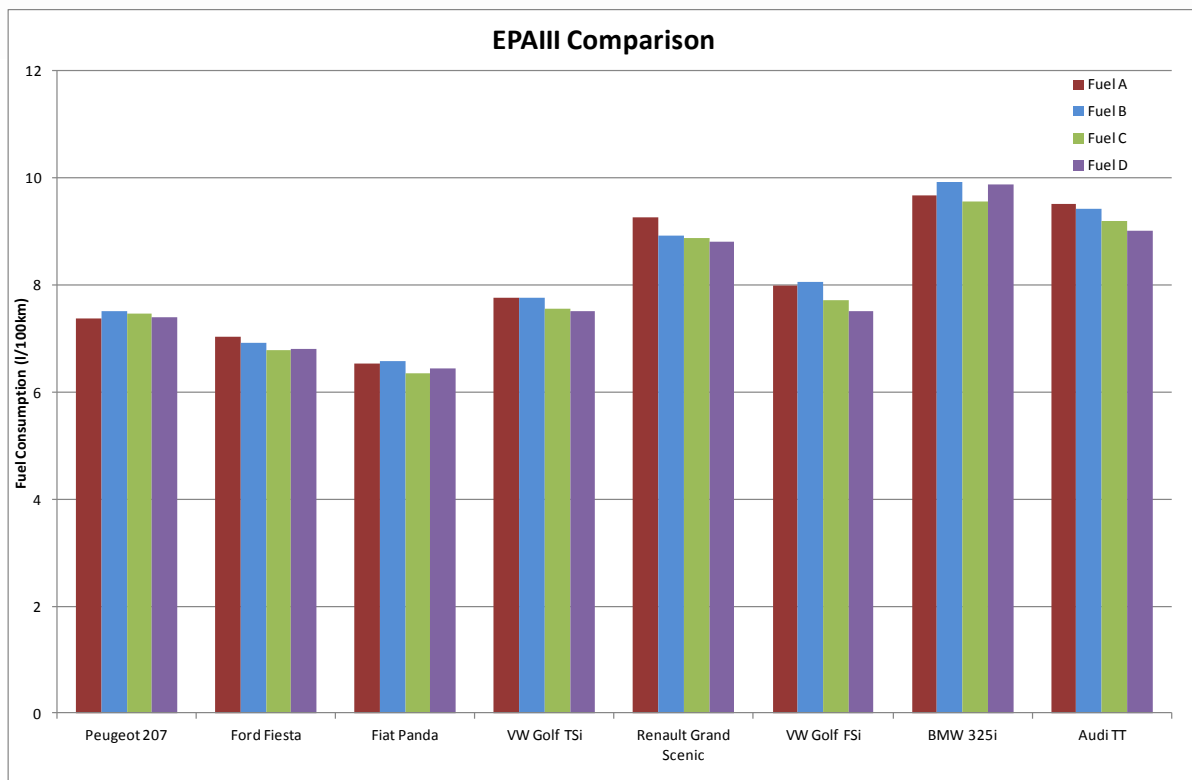


Figure 3 - EPAIII Comparison

Figure 3 shows the fuel consumption results of the 8 vehicles on the four test fuels over the EPAIII drive cycle. Each vehicle's results show the following:

1. Peugeot 207:
 - On Fuel A, the Peugeot 207 showed a fuel consumption of 7.384 l/100km.
 - Using Fuel B, the 207 showed a fuel consumption of 7.510 l/100km, a statistically significant increase of 1.72% on Fuel A.
 - Using Fuel C, the 207 showed a fuel consumption of 7.459 l/100km, a decrease of 0.69% on Fuel B. However, this result was not statistically significant.
 - Using Fuel D, the 207 showed a fuel consumption of 7.396 l/100km, a decrease of 0.83% on Fuel C. This result was also not statistically significant.
2. Ford Fiesta:
 - On Fuel A, the Ford Fiesta showed a fuel consumption of 7.031 l/100km.
 - Using Fuel B, the Fiesta showed a fuel consumption of 6.915 l/100km, a statistically significant decrease of 1.64% on Fuel A.
 - Using Fuel C, the Fiesta showed a fuel consumption of 6.774 l/100km, a statistically significant decrease of 2.05 % on Fuel B.
 - Using Fuel D, the Fiesta showed a fuel consumption of 6.802 l/100km, an increase of 0.42% on Fuel C. However, this result was not statistically significant.

3. Fiat Panda:

- On Fuel A, the Fiat Panda showed a fuel consumption of 6.524 l/100km.
- Using Fuel B, the Panda showed a fuel consumption of 6.577 l/100km, an increase of 0.81% on Fuel A. This result was not statistically significant.
- Using Fuel C, the Panda showed a fuel consumption of 6.347 l/100km, a statistically significant decrease of 3.49% on Fuel B.
- Using Fuel D, the Panda showed a fuel consumption of 6.432 l/100km, a statistically significant increase of 1.34% on Fuel C.

4. Volkswagen Golf TSi:

- On Fuel A, the Volkswagen Golf TSi showed a fuel consumption of 7.761 l/100km.
- Using Fuel B, the TSi Golf showed a fuel consumption of 7.751 l/100km, a decrease of 0.13% on Fuel A. However, this result was not statistically significant.
- Using Fuel C, the TSi Golf showed a fuel consumption of 7.552 l/100km, a statistically significant decrease of 2.57% on Fuel B.
- Using Fuel D, the TSi Golf showed a fuel consumption of 7.505 l/100km, a decrease of 0.63% on Fuel C. This result was not statistically significant.

5. Renault Grand Scenic:

- On Fuel A, the Renault Grand Scenic showed a fuel consumption of 9.252 l/100km.
- Using Fuel B, the Scenic showed a fuel consumption of 8.915 l/100km, a statistically significant decrease of 3.64% on Fuel A.
- Using Fuel C, the Scenic showed a fuel consumption of 8.870 l/100km, a decrease of 0.51% on Fuel B. However, this result was not statistically significant.
- Using Fuel D, the Scenic showed a fuel consumption of 8.819 l/100km, a statistically significant decrease of 0.58% on Fuel C.

6. Volkswagen Golf FSi:

- On Fuel A, the Volkswagen Golf FSi showed a fuel consumption of 7.978 l/100km.
- Using Fuel B, the FSi Golf showed a fuel consumption of 8.063 l/100km, a statistically significant increase of 1.07% on Fuel A.
- Using Fuel C, the FSi Golf showed a fuel consumption of 7.726 l/100km, a statistically significant decrease of 4.18% on Fuel B.
- Using Fuel D, the FSi Golf showed a fuel consumption of 7.512 l/100km, a statistically significant decrease of 2.78% on Fuel C.

7. BMW 325i:

- On Fuel A, the BMW 325i showed a fuel consumption of 9.671 l/100km.
- Using Fuel B, the 325i showed a fuel consumption of 9.914 l/100km, a statistically significant increase of 2.52% on Fuel A.
- Using Fuel C, the 325i showed a fuel consumption of 9.559 l/100km, a statistically significant decrease of 3.58% on Fuel B.
- Using Fuel D, the 325i showed a fuel consumption of 9.870 l/100km, a statistically significant increase of 3.25% on Fuel C.

8. Audi TT:

- On Fuel A, the Audi TT showed a fuel consumption of 9.517 l/100km.
- Using Fuel B, the TT showed a fuel consumption of 9.419 l/100km, a decrease of 1.03% on Fuel A. However, this result was not statistically significant.
- Using Fuel C, the TT showed a fuel consumption of 9.188 l/100km, a statistically significant decrease of 2.45% on Fuel B.
- Using Fuel D, the TT showed a fuel consumption of 9.002 l/100km, a statistically significant decrease of 2.03% on Fuel C.

On average, over all 8 of the test vehicles on the EPAIII drive cycle, Fuel B decreased fuel consumption by 0.04% compared to Fuel A. If only the statistically significant figures are considered, then the fuel consumption decreased by 0.005% compared to Fuel A.

Furthermore, Fuel C decreased the average fuel consumption over the 8 test vehicles by 2.44% compared to Fuel B. Considering only the statistically significant figures, then Fuel C decreased fuel consumption by 3.05% compared with Fuel B.

Finally, Fuel D decreased the average fuel consumption over the 8 test vehicles by 0.23% compared to Fuel C. Considering only statistically significant figures, then Fuel D decreased the average fuel consumption by 0.16% compared with Fuel C.

Valve and Injector Deposits

As well as evaluating the fuel consumption performance of each fuel, the level of inlet valve and injector deposits were also assessed to distinguish the level of clean up achieved from one fuel to the next.

This evaluation was performed using a borescope to photograph all inlet valves after testing on each fuel. In addition to this, all injectors were removed after testing and photographs were taken of each injector individually. These images were then passed to a qualified rater who then rated each inlet valve and injector based on its level of carbon deposits.

The assessment was performed on all 8 test vehicles, though only the port fuelled vehicles could be officially rated. The direct injection vehicles could not be rated as the fuel does not directly come into contact with the inside face of the inlet valves and therefore any deposits on the valves could not be related to the fuel. The Volkswagen Golf 1.4 TSi, Volkswagen Golf 1.6 FSi, BMW 325i and Audi TT were all direct injection vehicles and therefore their valve and injector images were not rated. However, images are still provided on the external media for reference purposes.

The Peugeot 207, Ford Fiesta, Fiat Panda and Renault Grand Scenic were port fuelled and thus inlet valve and injector deposits were rated accordingly. The rating scale used for this analysis ranged from a rating of 10 to 4.5, where 10 is completely free from deposits and 4.5 is completely fouled.

1. Peugeot 207:

- At the start of the fuel trial, the injectors could not be rated due to poor picture quality. All eight inlet valves were rated as 9.6-9.8.
- After Fuel A was tested, all four injectors were rated as being completely clean. All eight inlet valves were again rated as 9.6-9.8, suggesting no significant clean up occurred using Fuel A.
- After Fuel B was tested, all four injectors were again rated as clean. All eight inlet valves were rated as 9.6-9.8. This suggests no significant clean up on either injectors or inlet valves between Fuel B and Fuel A.
- After Fuel C was tested, all four injectors were rated as 9.0-9.5. All eight inlet valves were rated as 9.6-9.8. This suggests no significant clean up on inlet valves, but an increase in injector deposits between Fuel C and Fuel B.
- After Fuel D was tested, all four injectors were rated as 9.3-9.8. The eight inlet valves were rated as 9.6-9.8. This suggests no clean up in inlet valves between Fuel D and Fuel C, but a slight decrease in injector deposits.

2. Ford Fiesta:

- At the start of the fuel trial, the injectors could not be rated due to poor picture quality. All eight inlet valves were rated as 9.6-9.8.
- After Fuel A was tested, all four injectors were rated 7.0. All eight inlet valves were rated as 9.5-9.7, suggesting a slight increase in inlet valve deposits by using Fuel A.
- After Fuel B was tested, all four injectors were again rated as 7.0. All eight inlet valves were rated as 9.6-9.8. This suggests no significant clean up on injectors between Fuel B and Fuel A, but a slight decrease in inlet valve deposits.
- After Fuel C was tested, all four injectors were rated as 7.0-7.5. All eight inlet valves were rated as 9.5-9.7. This suggests no significant clean up on injectors between Fuel C and Fuel B, but a slight increase in inlet valve deposits.
- After Fuel D was tested, all four injectors were rated as 7.0-7.5. All eight inlet valves were rated as 9.6-9.8. This suggests no significant clean up on injectors, but a slight decrease in inlet valve deposits between Fuel D and Fuel C.

3. Fiat Panda:

- At the start of the fuel trial, the injectors could not be rated due to poor picture quality. Three of the four inlet valves were rated as 9.2-9.5 and the last inlet valve was rated as 9.5-9.7.
- After Fuel A was tested, all four injectors were rated 8.0. All four inlet valves were rated as 9.0-9.4, suggesting an increase in inlet valves deposits using Fuel A.
- After Fuel B was tested, all four injectors were again rated as 8.0. Two of the four inlet valves were rated as 9.5-9.7, one was rated 9.5-9.8 and the final valve was rated as 9.2-9.5. This suggests no significant

clean up in injector deposits, but a decrease in inlet valve deposits between Fuel B and Fuel A.

- After Fuel C was tested, all four injectors were rated as 7.5-8.0. The four inlet valves were rated as 9.0-9.5. This suggests no significant clean up on injectors between Fuel C and Fuel B, but an increase in inlet valves deposits.
- After Fuel D was tested, all four injectors were again rated as 7.5-8.0. The four inlet valves were rated as 9.2-9.6. This suggests no significant clean up on injectors, but a slight decrease in inlet valve deposits between Fuel D and Fuel C.

4. Renault Grand Scenic:

- At the start of the fuel trial, the injectors could not be rated due to poor picture quality. All eight inlet valves were rated as 9.6-9.8.
- After Fuel A was tested, all four injectors were rated as being completely clean. All eight inlet valves were rated as 9.6-9.8, suggesting no significant change in injector or inlet valve deposits using Fuel A.
- After Fuel B was tested, all four injectors were rated as 9.5. All eight inlet valves were rated as 9.3-9.6. This suggests an increase in both injector and inlet valves deposits between Fuel B and Fuel A.
- After Fuel C was tested, all four injectors were again rated as 9.5. All eight inlet valves were rated as 9.4-9.7. This suggests no significant clean up on the injectors, but a slight decrease in inlet valve deposits between Fuel C and Fuel B.
- After Fuel D was tested, all four injectors were again rated as 9.5. All eight inlet valves were rated as 9.5-9.8. This suggests no significant clean up on the injectors, but a slight decrease in inlet valve deposits between Fuel D and Fuel C.

From these results, it can be seen that after Fuel A testing, the Fiesta and the Panda showed a slight increase in inlet valve deposits, while the 207 and the Scenic showed no change in condition of inlet valves compared with the start of test results.

After Fuel B testing, the Fiesta and the Panda showed a slight decrease in inlet valve deposits, the 207 showed no change in either inlet valve or injector deposits and the Scenic showed an increase in both inlet valve and injector deposits compared with Fuel A results.

After Fuel C testing, the Scenic showed a slight decrease in inlet valve deposits, while the other three showed slightly more fouled results, with the Fiesta and Panda showing an increase in inlet valve deposits and the 207 showing an increase in injector deposits compared with Fuel B results.

After Fuel D testing, the Fiesta, Panda and Scenic showed a decrease in inlet valve deposits with no change in the condition of the injectors, while the 207 showed no change in the condition of the valves but a decrease in injector deposits compared with Fuel C results.

Test Results – Specific Bag Data

All bag summaries, modal emissions data and borescope images are provided on external media.

Photographic



Figure 4 - Peugeot 207



Figure 5 - Ford Fiesta



Figure 6 - Fiat Panda



Figure 7 - Volkswagen Golf TSi



Figure 8 - Renault Grand Scenic



Figure 9 - Volkswagen Golf FSi



Figure 10 - BMW 325i



Figure 11 - Audi TT

Appendices

Appendix A – The Two Sample t-Test for Independent Samples

The two sample t-test is a simple statistical model used to evaluate the significance of any difference between the means of two independent samples of data. To do this it is necessary to calculate a 'Test Value' which can then be compared to a figure from a look-up table known as a t-table (shown below). The figure is selected based upon the required confidence level and the degrees of freedom in the test data.

The necessary calculations are as follows:

Where;

- $\bar{x}_a$ is the larger of the two sample means
- $\bar{x}_b$ is the smaller of the two sample means
- n_a is the number of observations in $\bar{x}_a$
- n_b is the number of observations in $\bar{x}_b$
- df is the number of observations in each of the sample means
- SD is the standard deviation
- s is the combined SD

Before calculating the test value it is necessary to calculate s (the combined SD):

$$s = \sqrt{\frac{\sum df \times SD^2}{\sum df}}$$

Using this figure it is possible to calculate the test value:

$$\text{Test value} = \frac{|\bar{x}_a - \bar{x}_b|}{s \sqrt{\frac{1}{n_a} + \frac{1}{n_b}}}$$

If the calculated test value is greater than the figure selected from the t-table, it can be concluded that the difference between the mean samples is significant to the chosen level of confidence. If the calculated test value is less than the figure selected from the t-table, no conclusions can be made as to the significance of the difference between samples.

t-Table

Significance Level	10%	5%	2%	1%	0.2%	0.1%
	(0.1)	(0.05)	(0.02)	(0.01)	(0.002)	(0.001)
Degrees of Freedom						
1	6.31	12.71	31.82	63.66	318.31	636.62
2	2.92	4.30	6.97	9.92	22.33	31.60
3	2.35	3.18	4.54	5.84	10.21	12.92
4	2.13	2.78	3.75	4.60	7.17	8.61
5	2.02	2.57	3.37	4.03	5.89	6.87
6	1.94	2.45	3.14	3.71	5.21	5.96
7	1.89	2.36	3.00	3.50	4.79	5.41
8	1.86	2.31	2.90	3.36	4.50	5.04
9	1.83	2.26	2.82	3.25	4.30	4.78
10	1.81	2.23	2.76	3.17	4.14	4.59
11	1.80	2.20	2.72	3.11	4.03	4.44
12	1.78	2.18	2.68	3.06	3.93	4.32
13	1.77	2.16	2.65	3.01	3.85	4.22
14	1.76	2.15	2.62	2.98	3.79	4.14
15	1.75	2.13	2.60	2.95	3.73	4.07
16	1.75	2.12	2.58	2.92	3.69	4.02
17	1.74	2.11	2.57	2.90	3.65	3.97
18	1.73	2.10	2.55	2.88	3.61	3.92
19	1.73	2.09	2.54	2.86	3.58	3.88
20	1.72	2.08	2.53	2.85	3.55	3.85
25	1.71	2.06	2.49	2.78	3.45	3.72
30	1.70	2.04	2.46	2.75	3.39	3.65
40	1.68	2.02	2.42	2.70	3.31	3.55
60	1.67	2.00	2.39	2.66	3.23	3.46
120	1.66	1.98	2.36	2.62	3.16	3.37
Infinity	1.64	1.96	2.33	2.58	3.09	3.29
Confidence Level	90%	95%	98%	99%	99.8%	99.9%

Appendix B – New European Drive Cycle (NEDC)

Nearly all new car models which are type approved for sale in Europe have to undergo standard tests to determine their fuel consumption and exhaust emissions.

The New European Drive Cycle (NEDC), over which the exhaust emissions and fuel consumption of light duty vehicles is evaluated, consists of two phases (Urban (ECE) and Extra-Urban (EUDC) and is performed on a chassis dynamometer.

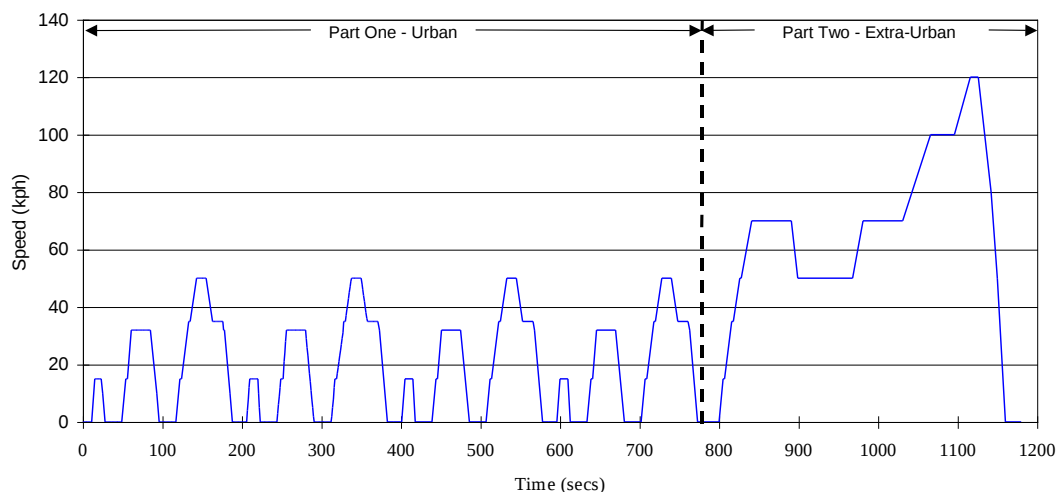
Urban Cycle

The urban test cycle is carried out in a laboratory at an ambient temperature of 20°C to 30°C on a rolling road from a cold start i.e. the engine has not run for several hours. The cycle consists of a series of accelerations, steady speeds, decelerations and idling. Maximum speed is 31mph (50 km/h), average speed 12 mph (19 km/h) and the distance covered is 2.5 miles (4km). The cycle is shown as Part One in the diagram below.

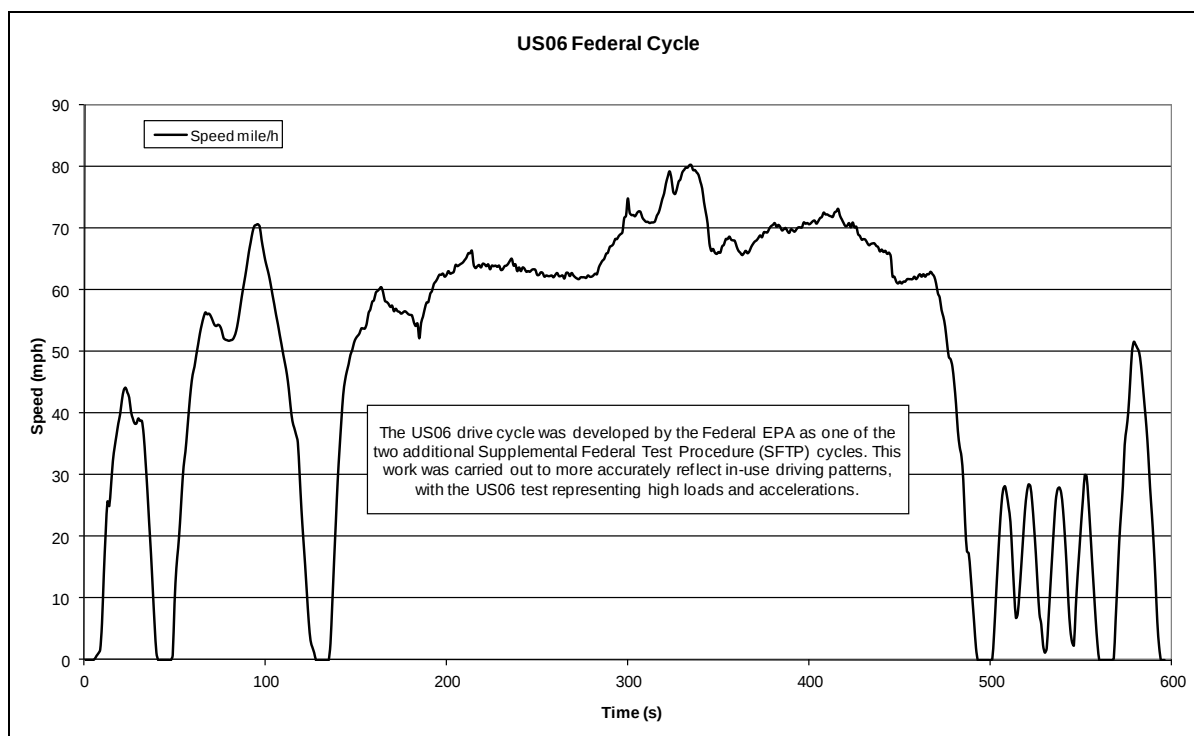
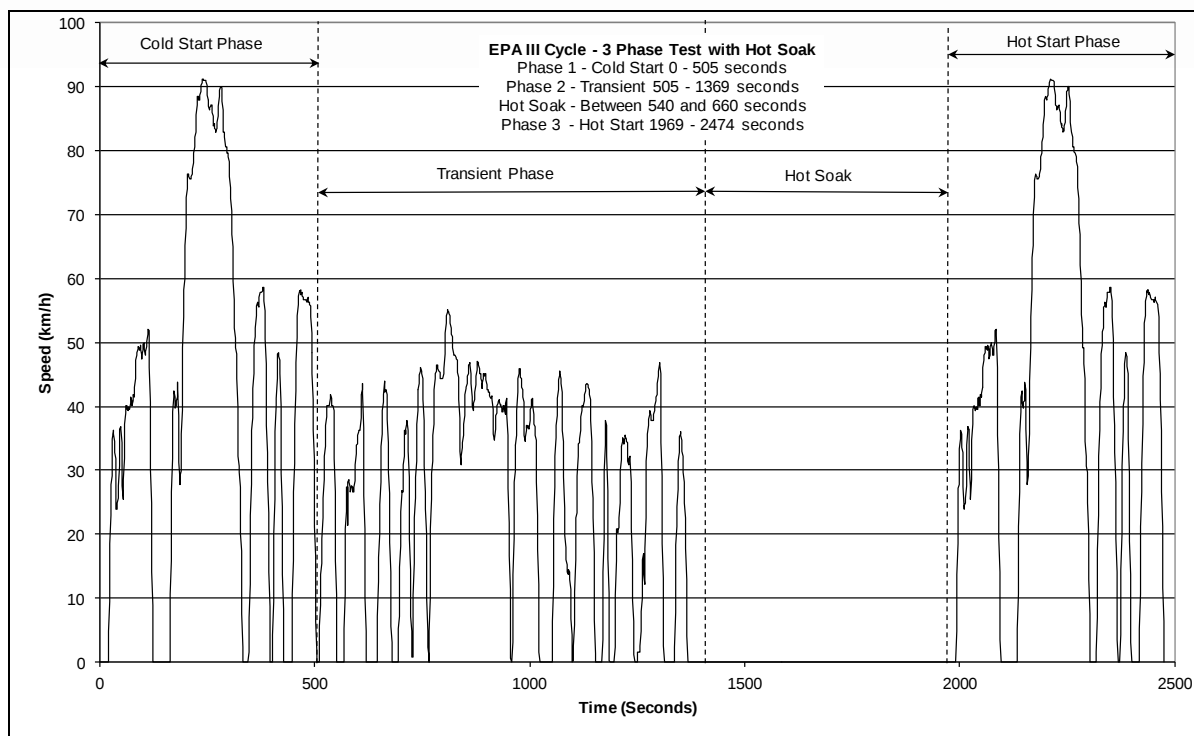
Extra-Urban Cycle

This cycle is conducted immediately following the urban cycle and consists of roughly half-steady speed driving and the remainder accelerations, decelerations and some idling. Maximum speed is 75 mph (120 km/h), average speed is 39 mph (63 km/h) and the distance covered is 4.3 miles (7km). The cycle is shown as Part Two in the diagram below.

New European Drive Cycle (NEDC)



Appendix C – Federal Drive Cycles (EPAIII and US06)



Millbrook OVERVIEW

Millbrook is one of Europe's leading locations for the development and demonstration of every type of land vehicle, from motorcycles and cars to commercial, military and off-road vehicles.

Millbrook's specialist expertise provides solutions in areas such as safety, performance and durability, and offers unrivalled new vehicle and propulsion technology programmes for areas such as hybrid, powertrain and fuel cell systems, adding significantly to the automotive industry's commitment to sustainable solutions. Our comprehensive portfolio of laboratories, as well as our iconic test track, are complemented by our manufacturing, homologation and conversion capabilities.

Millbrook is also a renowned events venue, playing host to some of the most innovative product launches and conferences of recent years, and has featured in several blockbuster films and TV programmes due to the huge variety of countryside, buildings and roads contained within our secure 700 acre site.



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