Comparison of emissions and fuel consumption of a passenger vehicle on two fuels

A report prepared for the Manildra Group of Companies

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Contents

1. Summary

This report summarises emissions testing undertaken on the same passenger vehicle (Table 3) when operating with two different fuels (Table 2). As requested by Manildra, this vehicle featured a Port Fuel Injected (PFI) engine. The first fuel tested was a commercially available, unleaded petrol (ULP). The second fuel was a mixture of that same ULP with 10% by volume ethanol added (E10). The testing was undertaken in one of the Test Cells of the Emission Laboratory at the Ford Australia node of the Advanced Centre for Automotive Research and Testing (ACART, www.acart.com.au). Experimental design, fuel preparation, analysis of test results and reporting was undertaken by the University of Melbourne node of ACART.

The averaged, cumulative emissions and fuel consumption over the New European Driving Cycle (NEDC) for the test vehicle running on E10 relative to the same vehicle running on ULP were as follows.

- Unburnt hydrocarbon emissions (HC, mg/km) were 15% lower.
- Carbon monoxide emissions (CO, mg/km) were unchanged.
- Oxides of nitrogen emissions (NO_x, mg/km) were 18% lower.
- Carbon dioxide emissions (CO_2, g/km) were 5% lower.
- Fuel consumption (l/100km) was 1% lower, which is considered negligible.
- Particle number (PN, #) was 26% lower.

The cumulative data for each of three runs on each fuel is presented in Table 1. The reported PN is a measure of the solid particles smaller than 2.5-10 µm, and is achieved using a measurement system that separates these smaller, solid particles from others in the exhaust.

It is noted that care must be exercised when considering the reported reductions above. A typical test for statistical significance might use a 95% confidence interval. Given the standard deviations of the data in Table 1, this would then suggest that these reductions are not statistically significant. However, imposition of a 95% confidence interval on the testing of the emissions *from any fuel or vehicle* can be problematic given the small number of emissions tests dictated by cost and duration constraints. Three tests for a given vehicle and fuel is common practice.

Nonetheless, the results presented in this report are consistent with other, recent research. In particular, research in the United States [1,2] has found neutral or favourable changes in HC, CO and NO_x emissions from PFI engines with increasing ethanol content in petrol. Numerous studies have also shown reduced particulate matter emissions with increasing ethanol content [1]. Whilst most of these studies were concerned with direct injection (DI) engines, the fundamental chemical and thermodynamic properties of petrol and ethanol should infer that PFI engines will also generate lower particulate emissions when running on ethanol-containing petrol.

Finally, DI engines typically produce more particulate emissions than PFI engines when running on the same fuel, and the increased uptake of DI engines is already well underway in the Australian and other new vehicle markets. The benefits of adding ethanol to petrol should therefore increase as DI engines take up a significant, and perhaps dominant, share of the on-road fleet over the next decade of so.

2. Methods

Emissions testing

All vehicle testing was undertaken in one of the Test Cells of the Emission Laboratory at the Ford Australia node of the Advanced Centre for Automotive Research and Testing [3]. This Laboratory is accredited by NATA to ISO 17025, and is approved by the Vehicle Certification Agency (VCA) for performing petrol, LPG and diesel tests to the European Euro 1 to Euro 6 legislation.

The testing presented in this report was undertaken to Australian Design Rule (ADR) 79/03, with measurement of the particle number (PN) added even though this is not required for this ADR. ADR 79/03 is the current Australian regulation for testing the emissions from new, petrol fuelled, light duty passenger vehicles. Complete specification of this testing procedure is given at [4].

The cumulative emissions from three runs on each fuel – ULP and E10 – are presented in Table 1. These runs were performed over the New European Driving Cycle (NEDC), with the cumulative emissions for HC, CO and NO_x measured using the 'bag' method. Cumulative emissions from second-by-second measurement of these emissions over the NEDC were also obtained, and these agreed closely with the results presented in Table 1. The PN measurements were obtained on a second-by-second basis.

ULP

Test #	*HC (mg/km)*	*CO (kg/km)*	*NOx (mg/km)*	*CO2 (g/km)*	*L/100km Combined*	*PN (#)*
1	26.58	259.52	18.68	234.18	10.13	1.20E+11
2	28.59	251.88	16.40	236.41	10.23	1.65E+11
3	27.83	269.71	22.50	231.94	10.04	1.33E+11
average	***27.67***	***260.37***	***19.19***	***234.18***	***10.13***	***1.39E+11***
std. dev. / av (%)	***3.7%***	***3.4%***	***16.1%***	***1.0%***	***0.9%***	***16.6%***

E10

Test #	*HC (mg/km)*	*CO (kg/km)*	*NOx (mg/km)*	*CO2 (g/km)*	*L/100km Combined*	*PN (#)*
1	28.43	303.82	18.64	224.48	10.04	1.47E+11
2	19.98	250.36	12.81	224.49	10.03	8.35E+10
3	21.92	225.15	15.90	221.04	9.88	7.73E+10
average	***23.44***	***259.78***	***15.78***	***223.34***	***9.98***	***1.03E+11***
std. dev. / av (%)	***18.9%***	***15.5%***	***18.5%***	***0.9%***	***0.9%***	***37.6%***

E10 relative to ULP

	HC (mg/km)	*CO (kg/km)*	*NOx (mg/km)*	*CO2 (g/km)*	*L/100km Combined*	*PN (#)*
(E10 av - ULP av) / ULP av	**-15%**	**0%**	**-18%**	**-5%**	**-1%**	**-26%**

Table 1: cumulative emissions for the Holden Captiva vehicle over the NEDC cycle when running on ULP and E10

Fuel preparation

Table 2 presents information on the commercially available, unleaded petrol (ULP) and ethanol used. The E10 used in the second set of emissions tests was obtained by 'splash blending' this ULP and ethanol on a 90%:10% volume basis.

	Vendor	*Purity*
Ethanol	VWR International	99.97%
ULP	Shell	-

Table 2: ULP and ethanol data

Vehicle specification

Table 3 presents information on the test vehicle used, a *Holden Captiva*.

Make	***Model***	***Variant***	***Fuel***	***Engine Configuration***	***Compression ratio***
Holden	CG Captiva 7	7 LS (2WD)	Petrol	Inline 4	10.4

Engine capacity	***Fuel delivery***	***Transmission***	***Gross Vehicle mass***	***Peak Power***	
				kW	***RPM***
2.4 L	PFI	Auto / 6 SPD	1810 kg	120	5600

Table 3: vehicle data

3. References

1. Stein, R., Anderson, J. and Wallington, T., "An Overview of the Effects of Ethanol-Gasoline Blends on SI Engine Performance, Fuel Efficiency, and Emissions," SAE Int. J. Engines 6(1):2013, doi:10.4271/2013-01-1635
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3. http://www.acart.com.au/index.php?page=Emissions
4. ADR 79/03, https://www.legislation.gov.au/Details/F2012C00283