Evaporative emissions and ethanol blends

Another technical contribution from the JRC/EUCAR/CONCAWE consortium

The JRC/EUCAR/CONCAWE consortium was set up in 2000 to carry out technical work of joint interest in the area of advanced fuels and vehicles. The first major output from the collaboration was the Well-to-Wheels analysis of future automotive fuels and associated power-trains, first published at the end of 2003 and updated version issued in May 2006.

The EU Fuels Directive Review, 2003/17/EC, provided a second major subject of common interest for all three consortium partners. This review included specific consideration of the current gasoline summer vapour pressure limits with respect to ethanol blending and technical data were needed. 'Splash'[1] blending of ethanol in standard gasoline would increase the vapour pressure by up to 10 kPa, potentially requiring an increase of the maximum specification from 60 kPa to 70 kPa, or the preparation of a special base fuel with lower vapour pressure for ethanol blending. The current summer limit of 60 kPa was set to control evaporative hydrocarbon emissions, and there is concern about the possible consequences of the increased vapour pressure of the ethanol/gasoline blends on evaporative emissions from gasoline cars.

In Europe, most of the data available on evaporative emissions had been obtained in studies carried out in the late 1980s on 'uncontrolled' vehicles and cars with first generation evaporative emission control systems. As fuels and vehicles have developed considerably since the late 1980s, there was a need for new data. For this reason CONCAWE, EUCAR and JRC decided to investigate the influence of vapour pressure and ethanol content on evaporative emissions from a range of current generation vehicle technologies. Representatives from the ethanol and ether producers were invited to join the programme as observers and provided input. This article is based on an interim report recently published (http://ies.jrc.ec.europa.eu/250.html). The full report, which will be available soon, will provide more in-depth information, in particular regarding the sensitivity of different cars to increased volatility.

[1] *Usual term to designate blending at a depot or terminal without quality adjustment.*

How are evaporative emissions controlled?

On-board evaporative emission control systems use carbon canisters to absorb gasoline vapours generated during normal running, 'hot soaks' after driving and 'diurnal losses' caused by daily temperature variation of the fuel tank. These vapours are then purged back to the engine during running conditions, with a complex control system also necessary for the whole system to function effectively. Although the vehicles are certified with a rigorous procedure, under extreme conditions such as extended high temperatures or exposure to high volatility fuels, it is possible that the carbon in the canister could become saturated and vapours could 'break through' and be emitted to the atmosphere.

Programme objectives and overview

The specific objectives of the joint JRC/EUCAR/CONCAWE programme were: to assess the effects of ethanol and vapour pressure on evaporative emissions from a range of latest generation canister-equipped gasoline cars; and to provide a firm technical basis for debates on gasoline vapour pressure limits in relation to ethanol blending for the Fuels Directive Review.

Seven vehicles of different sizes and makes, some of which were provided by the European Auto manufacturers and others hired, were tested on a fuel matrix consisting of fuels differing in ethanol content and vapour pressure (DVPE). All tests were carried out using the current regulatory evaporative HC emissions test procedure (see Directive 98-69-EC Annex VI, p. 27).

The test fuel matrix was composed of 60- and 70-kPa hydrocarbon base fuels with 5 and 10% ethanol splash blends as well as matched vapour pressure blends. The

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Table 1 Fuel properties

Fuel		A	A5S	A10S	A5E	A10E	B	B5S	B10S	B5E	B10E
DVPE	kPa	60.1	67.1	66.8	59.7	59.9	69.0	75.4	75.6	69.9	66.5
E70	%v/v	38.3	42.7	51.8	40.2	44.6	38.9	44.0	53.1	42.0	46.3
E100	%v/v	54.7	56.6	59.4	61.3	54.8	54.8	56.8	60.0	61.8	58.0
Ethanol	%v/v	0.0	4.5	9.5	4.7	10.3	0.0	4.7	9.8	4.9	9.7
Density	kg/m^3	755.5	757.2	758.7	747.1	756.0	753.3	754.3	756.0	747.1	750.0

two HC base fuels with DVPEs of 60 (fuel A) and 70 (fuel B) kPa represent (A) the current standard European summer grade gasoline and (B) summer grade gasoline specified in regions with 'severe winter conditions'. Based on these base fuels, blends with either 5% or 10% ethanol were prepared. The fuels with suffix 'S' were splash blends; those with suffix 'E' had their vapour pressure adjusted to match the DVPE of the base fuel. The fuel properties are shown in Table 1.

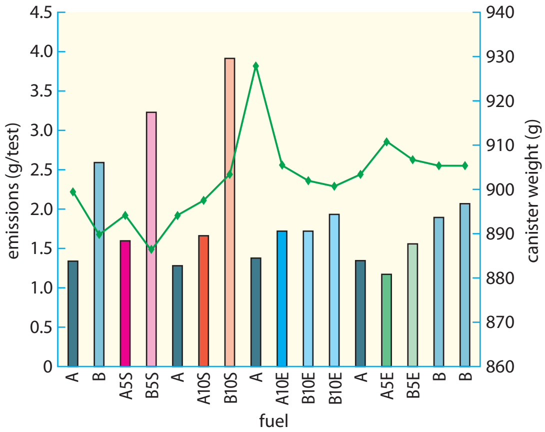
Key findings

The vehicles tested differed in their level of evaporative emissions and in the extent of their response to fuel changes (see Figures 1 and 2). All cars met the regulated 2 g/test emission limit on the first test on fuel A, the evaporative emissions reference fuel with DVPE of 60 kPa. Some vehicles slightly exceeded the limit on subsequent tests on this fuel, probably as a result of increased canister loading in later tests, as shown by the line graphs on Figures 1 and 2.

Figure 1 [a]

Effects of fuel changes on vehicle emissions: Vehicle 1

Vehicle 1 showed significant response to fuel changes, in particular with the high volatility ethanol blends, B5S and B10S

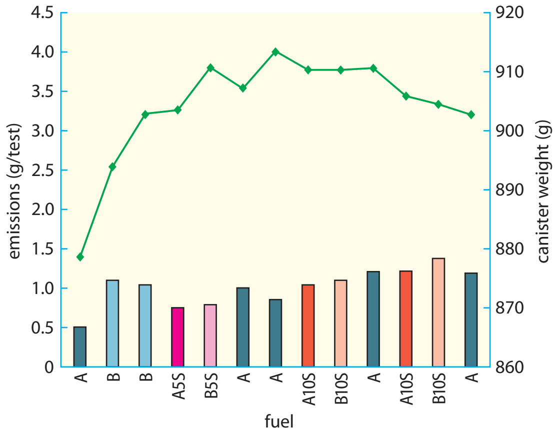


[a] *Note on Figures 1 and 2: Bars = Total Evaporative Emissions; Line = canister weight before testing*

Figure 2 [a]

Effects of fuel changes on vehicle emissions: Vehicle 2

Vehicle 2 was less sensitive to fuel changes and stayed within the EU's 2 g/test emissions limit on all fuels tested.



The key fuel variable that affects evaporative emissions is vapour pressure (DVPE). In general, increasing fuel vapour pressure above that of the reference fuel used for system development increased evaporative emissions. The effect appeared to be non-linear (as expected for a canister breakthrough effect). The ethanol blends with DVPE around 75 kPa gave considerably higher evaporative emissions than the other fuels in several tests over most of the vehicles (see Figures 3 and 4). Differences between the other fuels with DVPE in the range 60–70 kPa were small (see Figure 4).

Due to the combination of DVPE variations, the presence or absence of ethanol, and to significant changes of canister weight (see below) it is difficult to draw any reliable conclusions on the influence of each single parameter. The engineering margin built into the system may also explain the reduced fuel effect in this volatility range.

This programme has also shown that the test protocol used was not able to return the vehicle's carbon canister

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Figure 3
Effects of changes in vapour pressure (DVPE) on evaporative emissions: Vehicle 1

Vehicle 1 showed influence of increasing DVPE on total emissions. Ethanol blends at 75 kPa gave significantly higher emissions than the other fuels.

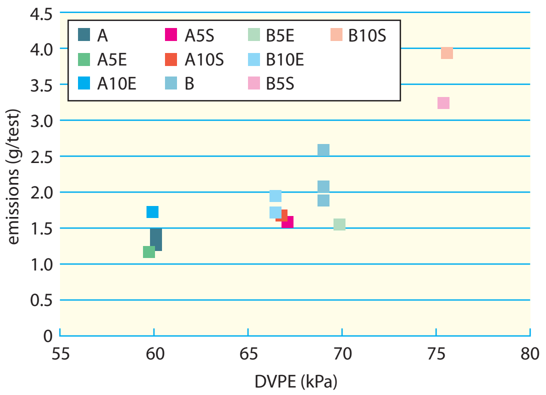
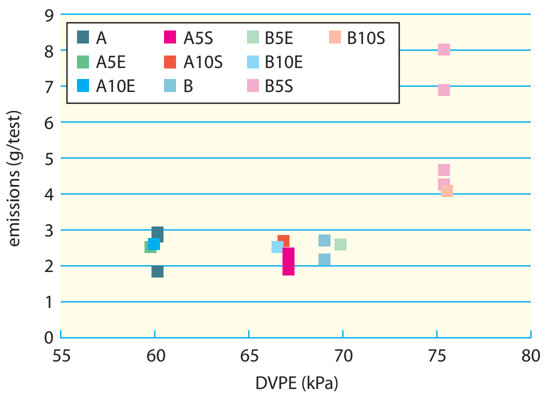


Figure 4
Effects of changes in vapour pressure (DVPE) on evaporative emissions: Vehicle 4

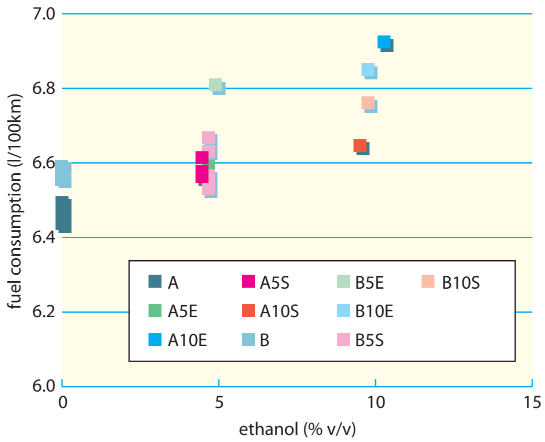
In Vehicle 4, ethanol blends at 75 kPa showed significantly higher emissions than the other fuels. Differences between fuels with DVPE <70 kPa were small.



system to a consistent condition at the start of each test. Repeating the test procedure without any additional driving between tests to purge the canister allows vapour to build up in the canister. This reduces its absorption capacity during the test and can increase emissions. This may not be representative of real-world operating conditions, but is a very severe test of the evaporative emission control system. Although the increase in emissions with repeated tests made it more difficult to discriminate fuel and vehicle effects, several clear conclusions could still be drawn from the results.

Volumetric fuel consumption (litres/100 km) increased with increasing ethanol content, as shown in Figure 5. This increase was roughly proportional to the oxygen content of the fuel. There was no clear effect on CO_2 emissions or energy consumption.

Figure 5
Observed increase in volumetric fuel consumption with increasing ethanol content: Vehicle 1



Application of results, limitations and potential further work

The test programme was designed to explore the effects of ethanol and fuel vapour pressure on evaporative emissions from a range of latest generation canister-equipped gasoline cars using the EU Evaporative Emissions test procedure. It has provided technical evidence on these effects, which should assist in the development of sound regulatory decisions under the EU Fuels Directive Review.

Not all aspects could be evaluated in this programme, e.g. parameters such as test temperature profile, presence of ethers in the fuel, fuel permeation and the long-term effect of ethanol and water on carbon canister working capacity could not be addressed due to limited experimental resources.

For any further work in this area, an improved canister conditioning procedure is needed to ensure that the canister system is properly conditioned to the new fuel at the start of each evaporative emissions test.