SLOVENSKI STANDARD

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Goriva za motorna vozila - Ocena vpliva bencina E10 na emisije in delovanje vozila

Automotive fuels - Assessing the effects of E10 petrol on vehicle emissions and performance

Kraftstoffe für Kraftfahrzeuge - Beurteilung der Auswirkung von E10-Kraftstoff auf Kraftfahrzeugemission und -leistung

Carburants pour automobiles - Evaluation des effets de l'essence E10 sur les émissions de véhicules et leurs performances

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Automotive fuels - Assessing the effects of E10 petrol on vehicle emissions and performance

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Kraftstoffe für Kraftfahrzeuge - Beurteilung der Auswirkung von E10-Kraftstoff auf Kraftfahrzeugemission und -leistung

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Foreword

This document (CEN/TR 16569:2013) has been prepared by Technical Committee CEN/TC 19 “Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin”, the secretariat of which is held by NEN.

1 Scope

This Technical Report describes a study executed to evaluate the performance of representative vehicles of current and recent production when operating on petrol fuels containing up to 10 % (*V/V*) ethanol. Vehicle performance evaluations included regulated and evaporative emissions as well as hot and cold weather driveability. The testing procedures used in each of the three main vehicle studies were adapted to the requirements of the testing facilities.

The studies were designed to demonstrate whether a relaxation in the $E70_{max}$, $E100_{max}$, and VLI limits in EN 228 would introduce unacceptable vehicle driveability or regulated emissions performance problems. The results were used to advise CEN/TC 19/WG 21 on the revision of the EN 228 petrol specification [1]. A procedure for future revision of EN 228 (see Annex A) was also developed.

2 Background

The former European EN 228 specification [1] included volatility requirements for unleaded petrol in order to ensure good performance of vehicles in real world driving conditions. These requirements were put in place following extensive technical studies in the 1990's at a time when vehicles were more sensitive to volatility than they are today and when blending of oxygenates, like ethanol, was not widespread. Different petrol volatility classes are included in the EN 228 specification that depend on climatic conditions. Minimum and maximum volatility limits for summer and winter petrols are included as well as additional limits for spring and autumn seasonal transitions.

Since these volatility requirements were put in place, the use of oxygenate blending components, such as ethanol and ethers, has increased, in response to the EU Renewable Energy Directive (RED, 2009/28/EC [3]). This Directive requires Member States to use at least 10 % renewable energy in transport fuels by 2020. Although biogas, renewable electricity, and other energy types are encouraged, only conventional and some advanced bio-blending components are likely to be available in sufficient volumes by 2020 to meet the mandate. The major bio-derived blending components until 2020 are likely to be bio-ethanol produced from sugar fermentation, ethers manufactured from bio-ethanol or bio-methanol, and esters and hydrocarbons produced from vegetable oils and animal fats.

Blending ethanol into gasoline at low concentrations alters the volatility characteristics of the resulting blend and the fuel refining and blending process shall account for this effect. In addition to increasing the vapour pressure of the ethanol/petrol blend, ethanol also changes the shape of the blend's distillation curve. This has the potential to impact the vehicle's regulated emissions and driveability performance in cold and hot weather. Furthermore, any change in the blend's distillation characteristics due to ethanol addition must be compensated in the refinery by changing the composition of the hydrocarbon-only petrol mixture into which the ethanol is ultimately blended.

Following the publication of the EU Fuels Quality Directive (FQD, 2009/30/EC [3]), CEN/TC 19 reviewed the European EN 228 unleaded petrol specification in order to enable the higher ethanol blending envisioned by the FQD from 5 % (*V/V*) up to 10 % (*V/V*). As input to this review, CEN/TC 19 Working Group 21 (WG 21) reviewed a 2009 study of published literature [4] on the effect of blending up to 20 % (*V/V*) ethanol on E70[1] and E100[2] volatility parameters, as well as on hot and cold weather vehicle driveability performance. This literature review was completed to better understand the observed effects on the petrol distillation curve due to the addition of higher levels of ethanol to petrol [5].

Any changes to CEN specifications for fuel parameters beyond those required by EU legislation should be based on the best-available technical data and shall not impact the performance of the vehicle fleet. Based on its review of the existing literature, WG 21 concluded that additional vehicle studies were warranted in order to assess the effects of 10 % (*V/V*) ethanol in petrol on current and future engines (Euro 5 and 6), especially with respect to vehicle regulated and evaporative emissions, CO_2, and hot and cold weather driveability performance.

Summer and winter grade petrols containing 10 % (*V/V*) ethanol were specially blended for this study that had volatility specifications at today's EN 228 maximum limits and at higher limits consistent with CONCAWE's volatility relaxation proposal. The vapour pressures (measured as Dry Vapour Pressure Equivalent (DVPE)) targeted summer grade petrols with a maximum 60 kPa DVPE and winter grade petrols with a maximum 100 kPa DVPE. The DVPE of the test fuel was selected to be consistent with the type of vehicle test that was completed.

[1] The percentage of a petrol sample that evaporates at 70 °C

[2] The percentage of a petrol sample that evaporates at 100 °C

In order to give sufficient technical input on behalf of CEN/TC 19 WG 21 members, a Volatility Task Force (VTF) was established in December 2010. Experts were nominated from WG 21 stakeholders and primarily from ACEA and CONCAWE, under the leadership of the WG 21 Chair and NEN Secretary.

The VTF met for the first time on 21 February 2011 and in total 21 meetings or web-conferences were held. Eight reports to WG 21 were issued and three presentations were given at WG 21 meetings.

3 Fuel selection

The VTF agreed to use a common set of specially blended test fuels to test the effect of the proposed relaxation in the volatility limits. The test fuels were based on early indications by CONCAWE on what qualities (mainly regarding volatility parameters) could be expected in the future when more refineries are supplying E10 fuels. Other options are also considered for the blending of E10 petrol, i.e. ETBE up to the 3,7% (*m/m*) oxygen content limit and ETBE + E5 blends up to the 3,7 % (*m/m*) oxygen content limit. The fuel matrix covered summer (class A) and winter (class E1) petrols as shown in Table 1.

Table 1 — Targets and measured values for test fuels

Baseline Fuels			
Summer (Class A)		**Winter (Class E1)**	
CEC RF-02-08 (Condition and pretest fuel)			
Target values:	Measured values:		
60 kPa DVPE$_{max}$ 5 % (*V/V*) Ethanol E70 mid-range E100 mid-range	58,7 kPa DVPE 4,7 % (*V/V*) Ethanol 37,0 % E70 53,5 % E100		
Baseline E10-A		**Baseline E10-E**	
Target values:	Measured values:	Target values:	Measured values:
60 kPa DVPE$_{max}$ 10 % (*V/V*) Ethanol 48 % E70$_{max}$ Class A 71 % E100$_{max}$ Class A	57,1 kPa DVPE 9,7 % (*V/V*) Ethanol 49,7 % E70 68,4 % E100 918,9 VLI	95 kPa DVPE 10 % (*V/V*) Ethanol 50 % E70$_{max}$ Class E 71 % E100$_{max}$ Class E	97,0 kPa DVPE 9,5 % (*V/V*) Ethanol 51,9 % E70 67,1 % E100 1333,3 VLI
Relaxed Volatility Fuels			
Summer (Class A)		**Winter (Class E1)**	
Step 1 E10-A		**Step 1 E10-E**	
Target values:	Measured values:	Target values:	Measured values:
60 kPa DVPEmax 10 % (V/V) Ethanol 52 % E70 (max+4 %) 73 % E100 (max+2 %)	58,7 kPa DVPE 9,5 % (V/V) Ethanol 52,9 % (V/V) E70 73,2 % (V/V) E100 957,3 VLI	95 kPa DVPE 10 % (V/V) Ethanol 54 % E70 (max+4 %) 73 % E100 (max+2 %)	93,2 kPa DVPE 9,5 % (V/V) Ethanol 54,9 % E70 70,9 % E100 1316,3 VLI
Step 2 E10-A		**Step 2 E10-E**	
Target values:	Measured values:	Target values:	Measured values:
60 kPa DVPEmax 10 % (V/V) Ethanol 58 % E70 (max+10 %) 75 % E100 (max+4 %)	61,0 kPa DVPE 9,4 % (V/V) Ethanol 59,4 % (V/V) E70 75,7 % (V/V) E100 1025,8 VLI	95 kPa DVPE 10 % (V/V) Ethanol 60 % E70 (max+10 %) 75 % E100 (max+4 %)	94,1 kPa DVPE 9,4 % (V/V) Ethanol 60,6 % E70 73,9 % E100 1365,2 VLI

4 CONCAWE vehicle study - High-level summary of results

CONCAWE tested six vehicles to investigate the impact of changes in the volatility characteristics of unleaded gasoline containing 10 % (*V/V)* ethanol on regulated exhaust and evaporative emissions and on hot and cold weather vehicle driveability performance. The vehicles selected for this study were representative of the current EU fleet, met or exceeded Euro 4 emissions limits, spanned the range from upper medium to small vehicle classes, were compatible with 10 % (*V/V*) ethanol according to the manufacturer's warranty information, and included two modern gasoline DISI engine types.

Table 2 — Characteristics of vehicles evaluated in the CONCAWE study

Vehicle No.	**1**	**2**	**3**	**4**	**5**	**6**
Vehicle Class	Upper Medium	Medium	Small	Lower Medium	Mini	Small
Category	M1	M1	M1	M1	M1	M1
Emissions Homologation	Euro 4	Euro 5	Euro 4	Euro 4	Euro 4	Euro 4
Engine Displacement (litres)	2.5	1.8	1.4	1.6	1.0	1.25
Max. Power (kW)	140	118	57	80.5	50	60
Inertia Class (kg)	1590	1470	1130	1360	910	1020
Cylinder	6	4	4	4	3	4
Valves	24	16	8	16	12	16
Aspiration	Natural	Turbo	Natural	Natural	Natural	Natural
Combustion Type	Homogeneous stoichiometric	Homogeneous stoichiometric	Homogeneous stoichiometric	Homogeneous stoichiometric	Homogeneous stoichiometric	Homogeneous stoichiometric
Injection System	Direct Injection	Direct Injection	Sequential Fuel Injection	Sequential Fuel Injection	Sequential Fuel Injection	Sequential Fuel Injection
After-treatment device	Three-way Catalyst	Three-way Catalyst	Three-way Catalyst	Three-way Catalyst	Three-way Catalyst	Three-way Catalyst
Rear or Front Wheel Drive	Rear	Front	Front	Front	Front	Front
Transmission	Manual 6-speed	Manual 6-speed	Manual 5-speed	Manual 6-speed	Manual 5-speed	Manual 5-speed
Drive by wire?	Yes	Yes	Yes	Yes	No	Yes
Traction control?	Yes	Yes	Yes	Yes	No	No
E10 Compatible?	Yes	Yes	Yes	Yes	Yes	Yes
Registration Date	15/06/2007	04/06/2009	29/09/2007	29/09/2009	23/07/2008	28/01/2010
Mileage at start of test (miles)	23,354	8,890	21,496	14,934	13,704	15,607

Vehicle testing included regulated emissions measured over the New European Driving Cycle (NEDC) at +23 °C and -7 °C, evaporative emissions according to the European regulatory procedure, cold engine starting and idling at -20 °C, and Hot Weather Driveability performance at +40 °C.

CONCAWE's conclusions from this study [6] were:

- All vehicles satisfactorily completed all required driving cycles on all fuels with no false starts, no misfires, no stalls, no failures, and no OBD faults.
- Impacts of fuel volatility on emissions and performance were small relative to vehicle-to-vehicle effects.
- No major differences were observed in the fleet-average HC and NOx emissions between the Baseline E10-A and Step 2 E10-A fuels for NEDC regulated emissions at +23 °C. The fleet-average CO emissions were 36 % higher on the more volatile Step 2 fuel but were still well below the Euro 4/5 limits for this test.
- No major differences were observed between the Baseline E10 and Step 2 E10 fuels for fleet-average NEDC regulated emissions at -7 °C and for HWD performance at +40 °C.
- Cold operation at -20 °C and -7 °C:
  - Overall conclusions:
    - > The measurement of lambda at these cold conditions was critical to understanding the in-cylinder conditions and the resulting impacts on emissions. The following conclusions apply particularly to the -20 °C results and to a limited extent the -7 °C results.
      - The exhaust UEGO sensor data indicated that the Step 2 E10-E fuel gave slightly richer lambda during the initial warm-up period. These results were not supported, however, by direct measurements of fuel and air flow, which suggested that there was no difference in AFR between the fuels.
      - The reason for these apparently conflicting results is not clear, but it is possible that the UEGO sensor responded to differences in exhaust composition between the two fuels rather than to a change in overall AFR. Alternatively, the lower volatility of the Baseline E10-E fuel may result in some fuel being retained on the cylinder wall during the initial cold engine conditions. If this were the case, then this fraction of fuel would not participate in the combustion process and would not appear in the exhaust gas.
      - Although conditions in the combustion chamber could not be directly measured, it can be expected that the more volatile Step 2 E10-E fuel should give better evaporation and mixing even in a cold combustion chamber. It is not clear whether the overall effects of this are beneficial or detrimental.

  - Cold starting and Idling at -20 °C:
    - > The tests comparing the Baseline E10-E fuel with the Step 2 E10-E fuel, having a difference in E70 of 8,7 %, showed:
      - All vehicles started easily (<1,6 s) and satisfactorily completed the 1180s test. Idle speeds were stable and consistent throughout and showed no differences between the fuels, although there were differences between vehicles in terms of fuel consumption, emissions, and time to reach lambda control.
      - Compared to the Baseline E10-E fuel, the more volatile Step 2 E10-E fuel produced more CO, less CO_2, and slightly lower levels of unburned HCs in the exhaust.
      - Limited tests comparing the Step 1 E10-E fuel with the Baseline E10-E fuel, which differed in E70 by 3 %, showed very similar emissions and starting performance.
- ECE regulated emissions at -7 °C:
  - The tests comparing the Baseline E10-E fuel with the Step 2 E10-E fuel, having a difference in E70 of 8,7 %, showed:
    - > CO and HC emissions on all fuels were well below the ECE regulated limits.
    - > Higher fleet-average CO emissions were measured on the Step 2 E10-E fuel although the effect was dominated by one DISI vehicle (Vehicle 2).
- Evaporative Emissions
  - Hot Soak Loss (HSL) emissions were low for all tests and fuels and the evaporative emissions results were dominated by diurnal emissions.

  - Three of the vehicles met the 2 g/test emission limit in all tests, but the other three vehicles consistently exceeded this limit, by up to 100 %.
  - Substantial differences were found between repeat tests on the same fuel, so the data were not adequate to carry out statistical analysis. However, there were no clear differences in emissions for any of the vehicles between the Baseline E10-A and Step 2 E10-A fuels.
  - Additional diurnal tests with extra carbon canisters connected to the vehicle canister vents showed that the diurnal emissions were not due to canister breakthrough, but from other sources, possibly including permeation through fuel system materials.
- Hot Weather Driveability (HWD) at +40 °C:
  - No overall increase in demerits was observed with the Step 2 E10-A fuel compared to the Baseline E10-A fuel for hesitations, stumbles and surges and for idle instability. For these demerit types 5 of 6 vehicles showed lower demerits on the Step 2 E10-A fuel, and one vehicle showed similar demerits on both fuels.
  - The two smaller vehicles showed higher demerits due to idle instability during Sequence 6 (heavy city traffic driving). This was due to greater idle speed variation than expected after throttle opening and closing.
  - Total demerits were higher than expected for all fuels when acceleration demerits were included, but these are believed to be due to the Engine Management System not allowing full throttle when demanded by the driver.

Overall, CONCAWE concluded that the results of this six-vehicle testing supported the conclusion from previously published studies that a small relaxation in the $E70_{max}$ and $E100_{max}$ volatility parameters in the EN 228 gasoline specification would not be expected to increase the risk of regulated emissions or vehicle driveability performance problems. The majority of the tests completed in this study compared results between ‘Baseline’ and ‘Step 2’ gasolines, in order to provide greater confidence that the performance of ‘Step 1’ gasolines would also be acceptable in real-world use. This conclusion applied to the current fleet of European gasoline vehicles as represented by the six E10-compatible vehicles selected for this study.

5 OEM vehicle studies - high-level summary of results

In order to help evaluate the changes to $E70_{min}$, $E70_{max}$ and $E100_{max}$ that were proposed by CONCAWE, four vehicle manufacturers undertook and funded individual test programs on a range of representative vehicles and fuels (see Annex B for details of the various tests and the fuels evaluated). The results of the tests are summarised in Table 3.

The results were discussed in the VTF in order that all stakeholders were able to review and question the results. Some of the 4 vehicle manufacturers also had additional discussions with representatives of oil companies where they have a working relationship.

The results on these new fuel formulations clearly showed that, under certain tests, fuel-related effects were observed at a level that the specific vehicle manufacturer categorised as being a concern when compared against vehicle sign-off criteria and also based on expert engineering judgement.

The vehicles tested were signed-off for production under the strictest engineering conditions using fuel formulations know at the time of sign-off. The tests demonstrated that there would be a risk that customers would experience problems using such ‘new fuels’ that are outside the validation area for the vehicles.

The vehicle manufacturers cannot accept any risk that their customers would experience problems using ‘new fuels’ that have not been evaluated in all the development and testing programs that are necessary to sign-off of new vehicles. Any complaints of poor vehicle operation would come directly to the vehicle manufacturers and their dealers and the vehicle manufacturers cannot accept this burden.

Table 3 — OEM study results

Summer Fuels	**Renault**	**PSA**	**Ford**	**Mercedes-Benz**
NEDC (+23 °C)	No Data	↑ CO Step 1	No Data	Step 2
NEDC (-7 °C)	No Data	No Data	No Data	Step 2
Cold Start (-20 °C)	Step 1	Step 1 lambda	No Data	Step 2 (at -25 °C)
HWD (+40 °C)	Step 1	No Data	No Data	Step 2 vapor lock
Evaporative Emissions	Step 1	No Data	No Data	Step 2
Winter Fuels				
NEDC (+23 °C)	No Data	↑ CO Step 1	Step 2	Step 2 CO above limit
NEDC (-7 °C)	No Data	No Data	Step 2	Step 2
Cold Start (-7 °C)	Step 1 (at 0 °C), lambda leaner, engine speed	No Data	Step 2 ↑Misfire	No Data
Cold Start (-20 °C)	Step 1 lambda leaner, potential for stalling	Step 1 lambda	Step 2	Step 2 (at -25C)
HWD (+40 °C)	Step 1 (at 30 °C) lack of richness	No Data	Step 2	Step 2 vapor lock and odour
Evaporative Emissions	Step 1	No Data	No Data	Step 2 slightly ↑

Colour Codes:

Green: no significant effects were observed;

Yellow: some effects were observed;

Red: effects were observed that the data originator categorized as a concern or a fail based on their engineering judgment and vehicle sign-off criteria.

In summary:

- Mercedes-Benz declared that the evaluated fuels were not accepted for their vehicles.
- Ford declared that the evaluated fuels were not accepted for their vehicles.
- PSA Peugeot Citroën declared that the evaluated fuels were not accepted for their vehicles.
- Renault declared that the evaluated fuels were not accepted for their vehicles.

In addition, vehicle manufacturers declared the results of these limited tests cannot be extrapolated to the whole vehicle fleet, current or planned.

The results of the test conducted by the four vehicle manufacturers were provided to WG 21 in document CEN/TC 19/WG 21/N 255 [7].