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Automotive fuels — Unleaded petrol containing more than 3,7 % (m/m) oxygen — Roadmap, test methods, and requirements for E10+ petrol

National foreword

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Carburants pour automobiles - Essence sans plomb contenant plus de 3,7 % (m/m) d'oxygène - Feuille de route, méthodes d'essai et exigences pour les essences E10+

Kraftstoffe für Kraftfahrzeuge - Unverbleiter Ottokraftstoff mit höheren Gehalten an Oxygenaten als 3,7 % (m/m) - Roadmap, Prüfverfahren und Anforderungen für E10+ Ottokraftstoff

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Contents

Foreword

This document (CEN/TR 16514:2013) 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

1 Scope

This Technical Report presents an overview and time plan for test methods and requirements that could be expected for future unleaded petrol and petrol blends in Europe. This means unleaded petrol with an ethanol/oxygenates level higher than allowed in the Fuels Quality Directive, Annex I [4], which is petrol containing up to 3,7 % (*m/m*) of oxygen, more familiarly known as E10.

Specific issues that may apply for certain levels or types of oxygenates are highlighted where appropriate in the appropriate sections of this report. This report does not take into account all issues related to vehicles that are specially designed to run on a much wider range of oxygenate contents above E10+, for example up to E85.

The report covers fuels and vehicle concepts for both E10+-capable (without engine efficiency gains) and E10+-optimised (with engine efficiency gains).

NOTE 1 Following the large possible combinations and levels of oxygenates, the work focuses on unleaded petrol with a nominal ethanol content between 10 % (*V/V*) and 25 % (*V/V*). Once the ethanol is higher than approximately 20 % to 25 % (depending on the vehicle) more engine and vehicle measures would likely be needed.

NOTE 2 For the purposes of this document, the terms "% (*m/m*)" and "% (*V/V*)" are used to represent the mass fraction, μ, and the volume fraction, φ, respectively.

NOTE 3 Although EN 228 speaks about and defines "unleaded petrol", the wording "petrol" is used throughout this document for the sake of readability.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 228, *Automotive fuels — Unleaded petrol — Requirements and test methods*

EN 14214, *Liquid petroleum products — Fatty acid methyl esters (FAME) for use in diesel engines and heating applications — Requirements and test methods*

EN 15376, *Automotive fuels — Ethanol as a blending component for petrol — Requirements and test methods*

3 Summary

This report provides an overview and time plan for test methods and requirements to be expected for future unleaded petrol containing oxygenate levels higher than currently allowed in the Fuels Quality Directive (FQD).[2],[3],[4] Before an E10+ petrol specification is developed in response to a legislative initiative, the following factors should be considered:

a) need for more research to define preferred and achievable specifications for an E10+ petrol blend;

b) need for adequate time to implement vehicle and fuel options, after an E10+ standard has been defined;

c) market introduction scenarios of the fuel supply and automotive industry, which general follow the steps:

    1) introduction of capable cars,

    2) build infrastructure for the availability of the fuels, and

   3) introduce optimised vehicles

d) need for EC funding to begin the necessary laboratory and vehicle testing.

E10+ petrol may be introduced for future new engine designs if benefits in regulated emissions, Tank-to-Wheels CO_2 and Well-to-Wheels CO_2 emission performance are demonstrated. These new designs could take advantage of the properties of an E10+ petrol to achieve these benefits, based on a higher oxygen content and a higher Octane Number (RON and MON). Because increasingly stringent vehicle regulations limit the regulated pollutants that a motor vehicle may emit, a future E10+ petrol standard may also require new limits for inorganic chlorides, phosphorus, sulfates and ash content, for example, in order to enable the performance and durability of both the engine and aftertreatment system. To ensure this performance, the impact of oxygen content higher than 3,7 % (*m/m*) in petrol on regulated pollutants, CO_2, vehicle driveability and pre-ignition and knock behaviour shall be studied in depth before an E10+ specification can be drafted.

The manufacture, distribution and sale of petrol containing higher oxygenate levels pose certain constraints and opportunities which shall also be considered. When ethanol is used as the primary oxygenate, for example, it can introduce some specific challenges that shall be carefully addressed, e.g.:

- effect of ethanol on vapour pressure, octane rating, distillation and related properties;

- tendency of ethanol to increase the dissolved water content of petrol;

- compatibility of materials in contact with both the liquid and vapour phases.

To facilitate any eventual marketing of E10+ petrol, new regulatory requirements should be agreed by the co-legislators in the European Parliament and the Council (on the basis of a Commission proposal) in consultation with industry stakeholders.

Finally, each specified or limiting fuel property shall be measurable by one or more test methods which have been verified to produce statistically relevant results at the expected levels of the property under investigation. In order to limit the scope regarding combinations and levels of oxygenates the focus for the test methods (Clause 9) is merely on petrol with a nominal ethanol content between 10 % (*V/V*) and 25 % (*V/V*). This focus is chosen as once the ethanol is higher than approximately 20 % to 25 % (depending on the vehicle) more engine and vehicle measures would likely be needed. This report discusses the likely applicability of current test methods for E10+ petrol and provides an estimate of the time and effort that would be required to verify applicability.

Assuming that the FQD is amended with the legal parameters of an E10+ petrol, a nominal specification for E10+ petrol, based on sound technical data, will take several years to develop and evaluate. Following this work, about five some additional years would be required to develop and commercialise E10+ capable vehicles, followed by up to five years to commercialise E10+ optimised vehicles and refuelling infrastructure. The path to successful implementation of an E10+ petrol grade will therefore be complicated, requiring considerable research on vehicles and test methods and coordination amongst all industry stakeholders.

EC funding may also be needed at an early stage to complement on-going stakeholder research and answer many of the technical questions that are related to E10+ petrol specifications and test methods.

This report considers issues related to E10+ petrol in the following four areas:

1) external drivers; policies and market drivers and constraints,

2) engine and vehicle; constraints related to component compatibility, emission and fuel consumption (challenges and opportunities), plus consumer reliability, and the possibilities to overcome those,

3) refinery, blending and logistics; constraints related to crude feedstock, process control, blending capacity and fuel station capability, plus inherent safety, and anticipating those,

4) test methods; applicability of existing techniques and needs to verify such.

Used abbreviations are presented in Annex A.

4 Context

The European Union is promoting renewable energy use in Europe and could encourage the extension of automotive petrol blended with higher fractions of renewably-sourced ethyl alcohol (referred to in this document as ethanol) and/or other oxygenates. Additionally, the EU has put in place stringent tailpipe pollutant emission limits and CO_2 targets for new vehicles sold in the EU market. It is uncertain at this point how these targets will influence the development of the European fuels market beyond 2020. Because vehicle performance and higher oxygenate levels shall be carefully assessed, harmonised fuel specifications are essential to ensure acceptable vehicle performance and durability in the market. The development of new fuels and vehicles is however a long and intensive process.

At the CEN/TC 19 meeting in May 2011, a priority was placed on “E10+” petrol in order to be prepared for future market and legislative decisions. It was agreed that a detailed assessment of biofuels and blends in Europe over the coming decade was needed that should be prepared through a multi-stakeholder approach. To develop this longer-term vision, CEN/TC 19 agreed to work together as Industry and Stakeholder partners to complete this assessment and outline the possible constraints and advantages of a future E10+ petrol.

Therefore CEN has combined efforts to draft this overview and time plan for test methods and requirements to be expected in the future. This work has been done with the participation of the convenors of test method working groups and vehicle and fuel experts from ACEA, CONCAWE, UPEI and e-PURE.

5 CEN/TC 19/WG 38

CEN/TC 19 requested WG 38 (New Fuels Coordination and Planning) to develop a CEN/TR that describes a European standardisation roadmap for future ‘E10+’ unleaded petrol. The scope of work was to draft an overview and time plan for test methods and requirements to be expected in the future. The experts that have contributed to this CEN/TR are known to the CEN/TC 19 Secretariat.

The working group has met on the following occasions so far:

— 21 December 2011, Amsterdam, 1st meeting;

— 3 April 2012, Delft, 2nd meeting;

— 22 August 2012, 3rd meeting (web-conference);

— 17 September 2012, 4th meeting (web-conference);

— 14 March 2013, 5th meeting.

6 External drivers

6.1 Introduction

In its 2009 legislation, the European Union adopted new policies to reduce Greenhouse Gas (GHG) emissions, improve energy security, and support agricultural development. Road transport was especially targeted by these policies because it is a major consumer of liquid fuels and contributes a significant percentage to total European GHG emissions. More importantly, road transport demand and associated GHG emissions have grown over the past decades and there are fewer alternatives in transport to reduce this growth compared to other energy-consuming sectors. The societal challenges associated with increasing access to personal and goods transport while steadily reducing GHG emissions and improving energy security are widely recognised. For this reason, the 2009 European climate and renewable energy legislation had several key elements as presented below.

6.2 Renewable Energy Directive (RED, 2009/28/EC)

The RED [5] mandated that at least 10 % of transport fuels on an energy basis shall be derived from sustainably produced, renewable sources by 2020. This can include the use of bio-blending components in fuels for road and non-road applications, the use of renewable electricity for vehicle recharging, biogas from waste materials, and other approaches.

Common products are those products derived from specific feedstocks, such as ethanol from sugar fermentation, ethers produced from renewable ethanol or methanol, and fatty acid methyl esters (FAME) and hydrocarbons produced from vegetable oils and animal fats. Pilot and commercial developments are progressing on new production pathways for many bio-blending components. These new developments may produce the same product but from a different feedstock or process (for instance, lignocellulosic ethanol). However, only the fairly common products are likely to be available in sufficient quantities to meet the 2020 mandate for transport fuels

6.3 Fuel Quality Directive (FQD, 2009/30/EC)

The FQD [4] requires that fuel suppliers reduce life-cycle GHG intensity associated with transport fuels by at least 6 % by 2020, versus a 2010 baseline. Historically, European refineries have improved their energy efficiency by about 0,5 %/year over the past 20 years at the same time that fuel demand has increased and product specifications have tightened. Energy efficiency improvements in the fuel manufacturing process can contribute to the FQD target but most of the mandated GHG reduction over this decade is expected to come from blending bio-components into fuels.

To achieve the FQD and RED mandates, these bio-components shall meet minimum GHG reduction thresholds that will change over the decade. They also shall be certified and audited as having been derived from sustainable sources and a number of EC-recognised certification schemes are now in place.

In addition, the FQD legislates the introduction into the market of ‘E10’ petrols, having up to 3,7 % (*m/m*) oxygen content and corresponding to 10 % (*V/V*) ethanol or appropriate volumes of ethers (MTBE or ETBE), higher alcohols, or other oxygenates (except methanol). Today’s E5 petrol, having a maximum of 2,7 % (*m/m*) oxygen and meeting EN 228 specifications, shall also be marketed for several years in order to ensure the performance of older petrol vehicles that are not fully compatible with higher oxygenate blends.

6.4 Vehicle CO_2 (Regulations 443/2009 and 510/2011)

Although new passenger vehicles and light-commercial vehicles shall meet stringent pollutant emissions requirements [6], they should also meet new fuel consumption limits on a fleet-average basis by manufacturer in order to increasingly reduce GHG emissions from the vehicle fleet.

For passenger cars, these new limits (Regulation 443/2009 [7]) are effective in 2015 and require that each manufacturer’s new vehicles achieve 130 g CO_2/km, on a fleet-average basis, through engine and vehicle performance improvements. The procedures for achieving the already defined target of 95g CO_2/km from 2020 are now being discussed. Similar targets (Regulation 510/2011 [8]) are now in place for light-commercial vehicles and are also being considered for commercial vehicles. A recent Commission proposal indicates that even lower CO_2 targets beyond 2020 will be developed by the EC by end-2014.

6.5 Today's situation

Today’s EN 228 specification allows blending of up to 3,7 % (*m/m*) oxygen in petrol (E10), either from ethanol, higher alcohols, or ether oxygenates. EN 228 also specifies a second petrol containing up to 2,7 % (*m/m*) oxygen (including E5) which is intended for older vehicles that are not compatible with higher oxygenate blends. The EN 590 diesel fuel specification [20] allows up to 7 % (*V/V*) FAME in diesel fuel (B7). Ethanol used for petrol blending shall comply with EN 15376 and FAME used for diesel fuel blending shall comply with EN 14214.

For diesel fuel, hydrocarbon-only blendstocks produced from natural vegetable or animal oils or from biomass are allowed and are generally less restricted in blending volume, subject to the requirements of EN 590, because they are very similar in composition to fossil fuels. Other work is also in progress to provide new opportunities and markets for biogas manufactured from waste and residues, dimethyl ether (DME) manufactured from pulp and paper products, renewable electricity, and other products that will help to achieve the legislated mandates.

In Europe today, more diesel fuel is sold than petrol even though there are currently more petrol cars than diesel cars in the total on-road fleet. This is because the number of new diesel cars purchased has increased over the past decade due to consumer preference and lower excise duty rates on diesel fuels in many countries. Freight transport in Europe is also dominated by on-road trucking which consumes considerable diesel fuel. The result is that there is currently a higher demand for diesel fuel and a lower demand for petrol than European refineries can easily produce. Refinery process technologies can only be adjusted within certain operational limits on the available crude oil supply.

Because of the existing imbalance in EU diesel/petrol production, Europe currently exports excess petrol production to North America and other regions and imports diesel fuel and jet/kerosene from Russia, the Middle East, and elsewhere. This import/export situation raises questions for the future regarding Europe's energy security and the sustainability of global trade for refined fuel products. New requirements for lower sulphur marine fuels as well as new environmental legislation are putting additional pressure on refineries. Although refineries are investing in new process units for increasing distillate fuel production, this imbalance in fuel demand is expected to continue for more than 10 years.

These factors mean that there is a clear market need for diesel blending components that meet the FQD and RED requirements and are fully compatible with diesel vehicles. This is proving to be a greater challenge than anticipated and the current blending limit for FAME in diesel fuel is limited while CEN/TC 19 work on the basis of an EC Mandate is in progress to increase the allowed level to 10 % (*V/V*) FAME (B10). Although some vehicles in captive fleets or niche markets can use diesel fuel containing higher FAME levels, such as B20-B30 or even B100, many vehicles are not compatible with FAME levels higher than B7. Similar to what is occurring for the introduction of E10 petrol, the market introduction of B10 diesel fuel would require vehicle compatibility lists and pump labelling to guide consumer purchasing and the continued marketing of a B7 grade for those vehicles that are not compatible with B10. In addition, the GHG reduction potential of many FAME products do not appear to be as good as for many petrol blending components.

Considerable work is in progress to accelerate the production of advanced renewable products for diesel fuel blending, such as the hydrotreated vegetable (and animal waste) oils (HVO) and biomass-to-liquid (BTL) products mentioned earlier. However, the pace of development of these product developments is slower than expected, with the possible exception of HVO, and they are not expected to make a big impact on renewable fuel supply in this decade.

Given these near-term problems on the diesel side, there is interest in considering more oxygenate blending above E10 in European petrol. However, because petrol represents a smaller fraction of the total European fuel demand, increasing oxygenate blending in petrol will also reduce the demand for petrol from crude oil and make the European diesel/petrol imbalance worse. In addition, increasing renewable blending components in petrol could reduce Tank-to-Wheels GHG emissions for petrol vehicles while increasing the Well-to-Tank GHG emissions at the same time from the combined petrol and diesel fuel supply. Thus, all factors shall be carefully considered which is the subject of this report.

Starting from the 2000 model year, most European vehicles are compatible with petrol containing up to 3,7 % (*m/m*) oxygen from ethanol or other allowed oxygenates. National specifications for E10 petrols are now in place in France, Germany, Finland, and Spain, while other countries are awaiting the outcome of

CEN/TC 19 discussions on a revised EN 228 specification. Specially adapted vehicles that can be fuelled with up to 85 % (*V/V*) ethanol (E85) are also available in some countries.

Since not all existing vehicles are E10 compatible (about 10 % of the petrol vehicles in Germany, for example), a ‘protection grade’ petrol (E5) has been mandated by the FQD to be marketed in parallel with E10 petrol. Recent market experience with the introduction of E10 petrol in Germany has shown that customer acceptance of the higher ethanol blend has not been strong and the corresponding sales of E10 petrol has been below expectation. The market share of E10 grade in the total gasoline sales more than one year after the introduction of the grade were about 15 % in Germany, 30 % in France and 60 % in Finland. This experience indicates that a future introduction of an E10+ petrol will require a coordinated introduction of compatible vehicles, fuel grades, and consumer awareness information in order to be successful. Key factors for success may be for instance a progressive launch of new fuel on a voluntary basis, an appropriately informed consumer and a broad availability of communication about vehicle compatibility.

Importantly, ethanol, produced from sugar or starch or manufactured from lignocellulosic biomass, exhibits some of the highest GHG reductions amongst the renewable products that are either readily available or in commercial development. ETBE, when manufactured from bio-ethanol, also has a 47 % renewable contribution and a GHG reduction that depends on the ethanol used. These products shall be independently certified as meeting minimum sustainability and GHG reduction requirements in order to qualify their use in fuels against the RED and FQD obligations. In the future, the GHG emissions performance of different fuel blends could well be valued on a Well-to-Wheels, rather than on a Tank-to-Wheels, basis.

Thus, there may be societal benefits to petrol fuels containing oxygenate levels higher than 3,7 % (*m/m*) oxygen if there is also consumer acceptance to further increase the renewable content of road fuels beyond the E5/E10, E85, and B7/B10 grades that are already envisioned for the EU-27. Rather, issues related to vehicle compatibility (both forward and backwards), fuel refining, blending, and logistics, test methods for E10+ specifications and implementation issues are discussed in detail. It is expected that the results of additional research and stakeholder discussion will be needed to define nominal specifications for this E10+ petrol at a later stage.

6.6 Factors to be considered

Regardless of the specification that is ultimately decided for E10+ petrol, there are several factors that should be considered:

6.6.1 Need for more research to define adequate E10+ specifications:

Currently, there are various ideas being explored through preliminary studies by different stakeholders in order to identify potential requirement for possible future E10+ specifications.

Based on these preliminary ideas, considerably more research will be needed by all industry stakeholders on possible E10+ formulations in order to validate potential performance and WTW GHG reduction benefits while minimising performance disadvantages, system inefficiencies, and added costs. This research will be directed towards narrowing the possible formulation options and establishing a nominal specification for a future E10+. Key parameters could include maximum and minimum oxygenate levels, minimum research and motor octane, and volatility requirements and definitions. It is also quite likely that new test procedures for vehicle cold and hot weather performance may be needed that take into account modern engine and vehicle control systems. The following specific areas have already been defined that will need more research:

a) Research (RON) and Motor (MON) Octane Numbers and Octane Sensitivity. This could include a new RUFIT (Rational Use of Fuels in Private Transport) study, as was conducted in the 1970s, to assess possible changes in engine design, RON/MON levels, crude oil utilisation, fuel manufacturing costs, and GHG reductions on a Well-to-Wheels basis.

b) Impact of E10+ volatility on:

    1) Lambda deviations and exhaust emissions under cold engine starting conditions;

  2) Cold engine starting and drivability performance;

  3) Hot weather starting, vapour lock, and drivability performance;

  4) Evaporative emissions;

c) Materials compatibility with elastomers and gaskets in vehicles and in the fuel supply and distribution system;

d) Materials compatibility issues with metallic alloys and fuel system components;

e) Valve seat recession, cylinder liner wear, and cam lobe wear with higher ethanol fuels;

f) Lube oil dilution by fuel and faster than expected loss in lube quality;

g) Fuel system deposit control on intake valves and in the combustion chamber;

h) Fuel and lube system additives specially adapted to higher ethanol levels;

i) After-treatment systems that are fully compatible with higher ethanol/petrol blends;

j) Sensor technologies for engines and after-treatment systems;

k) Vehicle durability testing.

6.6.2 Need for adequate time to implement vehicle and fuel options:

From previous experience with the revision of EN 228 to include E10 petrol, a transition to E10+ shall allow sufficient lead time for implementation. To put this in perspective, even a relatively limited laboratory and vehicle study aimed at defining the specifications for E10+ will take several years to organise and execute with the cooperation of all stakeholders. After this, a CEN standard would need to be developed requiring at least an additional three years. Vehicle industry experts also estimate that about five years would be required to develop E10+ compatible vehicles once a nominal specification for E10+ petrol has been defined. This time does not seem unreasonable given the simultaneous requirements for vehicles to meet lower CO_2 and Euro 6+ emissions limits, long-term vehicle durability requirements, and in-use compliance performance.

As E10+ compatible vehicles are introduced into the on-road fleet, the market introduction of E10+ petrol would need to be coordinated in order to encourage the penetration of E10+ compatible vehicles. Since there will be older vehicles in the fleet that are not E10+ compatible, a ‘protection grade’ fuel will be needed for some time (E5 or E10 depending on when an E10+ grade is introduced). This means that there is little expectation that an E10+ grade can be implemented quickly enough, compared to other fuels such as E85, to significantly impact the 2020 RED and FQD targets.

6.7 Final remarks on external drivers

The path to a successful commercialisation of an E10+ petrol grade will be complicated, requiring considerable research on vehicles and test methods and coordination amongst all industry stakeholders. The vehicle industry’s current view is that there will not be backwards compatibility of a future E10+ grade with the existing on-road fleet so that some type of ‘protection grade’ will be needed in the future. This point will need to be considered as one aspect of E10+ implementation.

While this report begins to describe a future state for an E10+ petrol, it is also very important to point out that the much nearer-term target and priority is a successful and pan-European implementation of E10 petrol and B7 diesel grades, including pump labelling and the ready availability of consumer awareness information. Getting this implementation right will ensure that Europe is on the right trajectory to future GHG reduction in road transport with consumers who are fully informed and engaged.

7 Engine and vehicle concepts and techniques

7.1 Summary points

1) The roadmap for the completion of the 95 g CO_2/km target for that applies from 2020 onwards, possible CO_2 targets beyond 2020 and the completion of the Euro 6 emission requirements, including the introduction of new test cycles, imposes a limitation as to when an E10+ petrol could be introduced in terms of the new vehicle development timetables and the complete compatibility of new vehicles to use an E10+ petrol.

2) An E10+ petrol will be for future new vehicle technologies only. Backwards compatibility with current vehicles and vehicles introduced in the coming years cannot be ensured, although it is the car manufacturers' responsibility to communicate on backwards compatibility for their own cars.

3) E10+ petrol with higher oxygen content could offer opportunities to introduce new engine/vehicle designs that can take advantage of the characteristics of an E10+ petrol in terms of reduced tailpipe CO_2 and certain regulated emissions, depending on the higher minimum oxygenates content and the accordingly increased Research Octane Number and Motor Octane Number. Both parameters need to be increased in a completely new E10+ petrol standard in order to gain a Tank-to-Wheels CO_2 benefit.

4) The impact of a highly oxygenated fuel on currently and potentially future regulated pollutants, CO_2 and vehicle driveability needs to be studied in depth.

5) Engine calibration potential needs to be taken into account. If an E10+ petrol could have a narrow min/max ethanol or oxygenate range around the specified maximum, there could be advantages for engine efficiency and to help optimise the design and calibration of future engines. E10+ reference fuels should reflect what can be expected in the marketplace.

6) Today MON is a parameter also for describing low and high-speed pre-ignition. RON – measured with an appropriately modified CFR engine for higher oxygenated fuel – correlates well with knock behaviour even at modern downsized turbo charged direct injection engines, at least for pure hydrocarbons or low ethanol blended petrol (<10 % (*V/V*) ethanol), but even for higher ethanol blends (>10 % (*V/V*)) as long as only moderately retarded combustion is applied (Centre of Combustion – CA50 needs to be approximately 12 ° below the CA ATDC [12]). The phenomena of pre-ignition and knock behaviour in high boost-level engines operating at even higher BMEP levels may require a completely new approach and modifications to existing test methods or new test method developments.

7) The sensitivity between RON-MON for high ethanol/oxygenate blended petrol needs assessment taking these issues into consideration.

8) A suitable RON/MON test method with sufficiently proven accuracy range needs to be addressed for petrol containing more than 4,0 % (*m/m*) oxygen (e.g. E101+). DIN 51756-7 [13] – describing modifications of the CFR engine – is a good basis for the development of a new standard.

9) Access to leaded Primary Reference Fuels (PFR) or the definition of (new) PRFs for RON/MON testing (in accordance to EN ISO 5163 [9] /EN ISO 5164 [10]) for RON > 100 need to be addressed.

10) The driveability indicators e.g. vapour pressure and distillation, will need to be controlled seasonally as in EN 228 and in such a way that vehicle driveability effects are limited. For this it might be necessary to identify new descriptors and their appropriate ranges to guarantee the proper functioning of future engines.

11) New limits will need to be established for the blending components and the final E10+ petrol blend. EN 15376 could be possibly be revised to take into account the effect of trace contaminants (sulphate, chlorides,...) on vehicle components and exhaust after treatment systems.

12) The vehicle and engine technology that would be needed to meet possible future emission and CO_2 targets that EU legislators might establish beyond 2020 are presently not known. Matching the specifications of an E10+ petrol with future (unknown) vehicle and engine technology will require substantial research.

7.2 Current and future constraints for an E10+ petrol

7.2.1 Existing Euro 6 and CO_2 legislative roadmap

Euro 6 still has many open issues and the roadmap is complicated and unclear.

New measures scheduled to be introduced into legislation to apply in the 2020 timeframe or later include:

- new test cycle and procedures for CO_2 and emissions (WLTP);
- new tests (real driving emission tests);
- tighter OBD and cold start emission limits (covering also diesel NOx);
- more extensive evaporative emission test;
- presently, Euro 6(a) applies from 2014/2015 and Euro 6(b) applies from 2017/2108.

The introduction of an E10+ petrol will eventually be reflected in the test reference fuel (since test reference fuel is supposed to reflect market average). However, should an E10+ test reference fuel be mandated before it is widely introduced into the market or later? The test fuel needs to be known well in advance for efficient engine design and calibration but a test reference fuel could not be defined until there is a clear view of the parameters and methods needed to fully describe an E10+ market fuel in a completely new standard.

The introduction of an E10+ petrol would require amendment to the Fuel Quality Directive, completion of a robust and fit-for-purpose CEN standard and then suitable lead-time for industry (auto and oil) to develop and deliver the fuel and the vehicles to the market.

The already on-going discussions of all the above new legislative requirements for Euro 6, etc. should only be based on an E10 (or B7) reference fuel at this time. Introduction of a new reference fuel reflecting a future E10+ petrol would need rather more time, i.e. at a compatible date reasonably beyond Euro 6(b) from 2017/2018 and from when the specifications of any E10+ market petrol is defined.

7.2.2 Recommendations for new vehicle concepts

An E10+ petrol can only be considered looking forwards. Backwards compatibility with the older vehicle fleet (including at that time the E10 compatible vehicle fleet) cannot be considered.

The introduction of future engine concepts that can meet the demands of EU legislation and new market fuel developments needs lead-time according to a defined legislative timetable, a period of regulatory stability to allow recuperation of investments and a common and harmonised roadmap for the introduction of new fuels across the EU without market fragmentation.

To help meet future passenger car / light-commercial vehicle CO_2 legislation, i.e. the 95 g CO_2/km target applicable from 2020 onwards and the development of any legislative target set beyond that date, it is important to investigate:

- opportunities for increasing the engine compression ratio and any limitations imposed in terms of engine on downsizing when using new high-octane fuels (boosted octane by increased ethanol content or other preferred oxygenate, when minimum ethanol content in accordance with increased RON/MON is specified);

- impact on OBD monitoring capability;
- impact on the durability of emission control systems;
- impact on evaporative emission control systems;
- at what guaranteed ethanol level would a vehicle manufacturer choose to go the flex-fuel route while meeting emissions legislation (Type 1 and Type 6 tests) and cost-effective CO_2 benefits?

7.2.3 Engine calibration potential

What range of ethanol content (or oxygen range) in petrol will future engine concepts be able to deal with? It is certainly highly desirable that the range between min and max ethanol content (or min and max oxygenate content) is narrow, approximately 5 %(*V/V)* in the case of ethanol content.

What is the effect of such a narrow ethanol / oxygen range on regulated pollutant emissions, currently non-regulated emissions and CO_2? It is well known that a broad range makes it more difficult for vehicle driveability and emissions calibration, less CO_2 reduction potential due to lower minimum oxygenate content and accordingly lower minimum RON. How far could a narrow range be ‘stretched’ while still attaining all design, performance and legislative requirements?

Will new engine technologies which are expected to be introduced to help meet future EU legislation, (e.g. high pressure pump) likely to bring new constraints on fuel specification?

Could a new car be optimised to run on a narrow E10+ petrol range most efficiently (e.g. narrow range between min and max ethanol content) also run on E10 petrol if the E10+ petrol was not available? What would be the extent of performance loss and fuel economy deterioration? How is the vehicle cold and hot driveability affected?

The parameters in an E10+ petrol that will affect future engine/powertrain developments and the achievement of low regulated (and presently non-regulated) pollutant and CO_2 emissions need to be defined, including the ‘range’ of those parameters that could be possibly handled by future engine calibration/designs.

7.2.4 Potential for new pollutants in legislation

Will an E10+ petrol lead to new, presently unregulated, pollutants being identified by the legislator (e.g. HC speciation)?

What will be the impact of an E10+ petrol on vehicle-source emissions (tailpipe, evaporative, other)?

7.2.5 Impact on vehicle and fuel system components

The potential evaporative emissions from an E10+ petrol need to be considered in respect of:

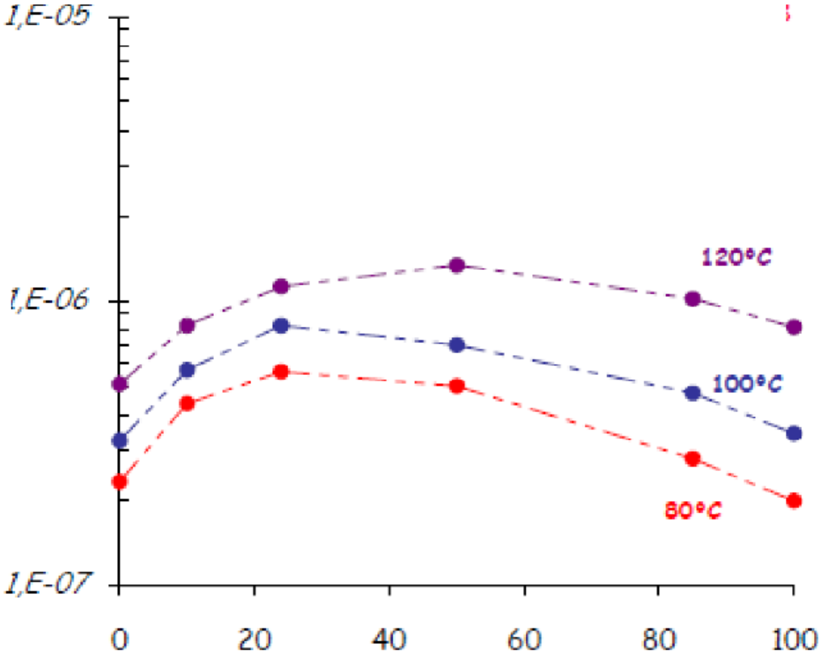
- Diurnal and hot-soak emissions during the more rigorous evaporative emissions test that will be introduced during Euro 6. Presently the European Commission plans to extend the current 24 h test to 48 hours and add requirements for ensuring the durability of the evaporative control system.
- Permeation of fuel molecules through elastomeric materials (rubber and plastic parts and other components) used in the vehicle’s fuel and fuel vapour handling systems. As seen in Figure 1, the permeability of certain elastomers or rubbers can be modified following the ethanol content. Depending on the elastomer used, a reduced range of ethanol content is required below or after the maxima of permeability (E22) to avoid the disappearance of the plasticisers and to ensure the durability of these components.
- Permeation through vehicle fuel tanks.

- Effects of an E10+ petrol on the durability of evaporative emission control systems, the ability to control evaporative emissions to the regulated limit over 160 000 km durability period.
- Temperature effects - with the future emphasis on real driving emissions, the control and range of temperature of the legislative tests will become more severe.

7.2.6 Higher consumption

With higher ethanol content, the volumetric consumption will be higher.

Improved RON/MON can help to partly compensate the volumetric fuel economy penalty, approximately 2 % for every 5 % (*V/V)* of ethanol (at the same engine efficiency, which means same energy consumption). This effect is different for other oxygenates. Optimisation of engine design and calibration can assist in the compensation (see 7.4.3).



Key

X-axis	ethanol % (*V/V*)	Y-axis	permeability (*Pe* in g cm/cm^2 s)

Figure 1 — Example of ethanol effect on NBR/PVC elastomer permeability

7.3 Opportunities for an E10+ petrol

7.3.1 Helping reduce pollutant emissions and CO_2

An E10+ petrol can result in lower tailpipe CO_2 emissions when used in new high efficiency engines with high compression ratio and / or in more aggressively downsized engines.

E5 and E10 (and the ETBE equivalents) were introduced for additional reasons including, amongst others, CO_2 savings elsewhere in the life cycle. This argument would apply to an E10+ petrol irrespective of whether or not advantage is taken of the higher octane.

Specifically for future cars, engine and vehicle optimisation to the E10+ petrol, depending on the vehicle technology to be introduced, could improve the CO_2/km performance of new vehicles. New CO_2/km targets will be established beyond 2020 that could be aided by engine efficiency gains on a higher RON and MON fuel (see below).

There may be potential for higher RON and MON petrol and higher knock resistance to help reduce particle emissions from GDI engines - this needs further exploration.

7.3.2 Current cars

IMPORTANT — This section is included as information as current cars won't in general be using an E10+ petrol in the future.

Adding oxygenates to petrol will induce a lean shift in engine stoichiometry which, in turn, will reduce carbon monoxide (CO) emissions on non-compatible carburetted vehicles without electronic feedback controlled fuel systems. But at the same time NOx emissions will be significantly increased by the lean combustion with excess oxygen.

More modern vehicles (approx. since mid-1980s) are equipped with 3-way-catalysts and thus with an electronic lambda control system which always sets lambda to 1 during warm part load operation. The lambda control can, to a certain extent, compensate for fuel oxygen content. However, above this oxygen content in the fuel, closed loop lambda controlled vehicles will also see a considerable increase in NOx accompanied by a slight HC and CO reduction.

During cold start and full load operation the lambda control is inactive. Operation parameters in those modes are partly adopted by long-term adaption strategies. Once the lambda control leaves the pre-determined control range also those parameters are no more adopted. This can lead to cold start and warm up issues (engine stall, poor drivability, increased HC emission) and (at full load) also to reduced component cooling due to full load enleanment. The higher component temperatures are hazardous for engine and exhaust gas aftertreatment system durability and can significantly reduce the lifetime of the engine. Reduced durability of the exhaust gas aftertreatment system might have a negative effect on long term emissions.

Fuel-leaning caused by oxygenates can cause tailpipe emissions to increase, depending on the leanness of the engine's base calibration with non-oxygenated petrol.

More recent testing by the Coordinating Research Council (CRC) on newer vehicles has produced similar results (CRC E-67).

7.4 High oxygenate fuel combustibility determination (RON/MON) for an E10+ petrol

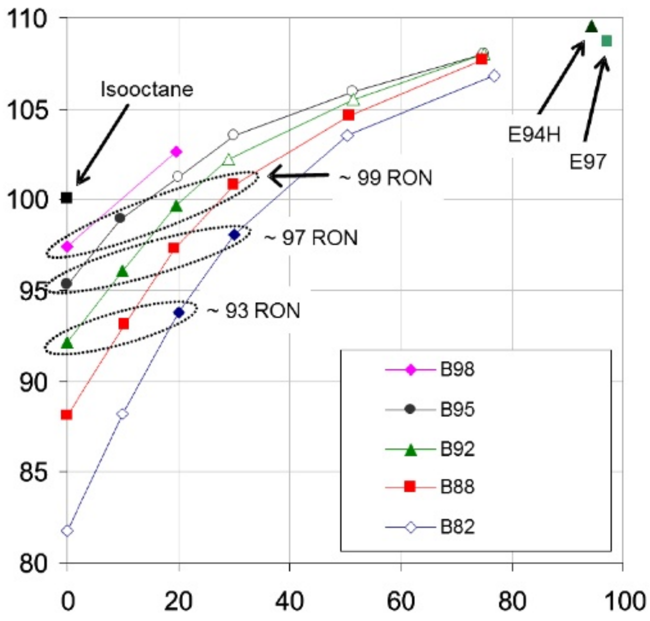
NOTE Due to available data, this section primarily concentrates on ethanol. The effect of other oxygenates will need to be also considered in future studies.

7.4.1 RON-MON relationship

Ethanol is a significant octane booster. It delivers more octane than crude-originating refinery hydrocarbon streams. The boosting effect depends on the composition of the base fuel and the base RON of the blend-stock. The lower the blend-stock RON, the higher the boosting effect.

Ethanol boosting effects are shown in Figure 2 [12].

NOTE The data were determined with two decent methods utilising 2 differently modified CFR engines. First, a Dresser Waukesha CFR XCP2 engine, with variable fuel pump speed, secondly a modified CFR engines with a variable nozzle in accordance to DIN 51756–7 (variable nozzle) [13]. Both methods deliver more or less exactly the same RON results.



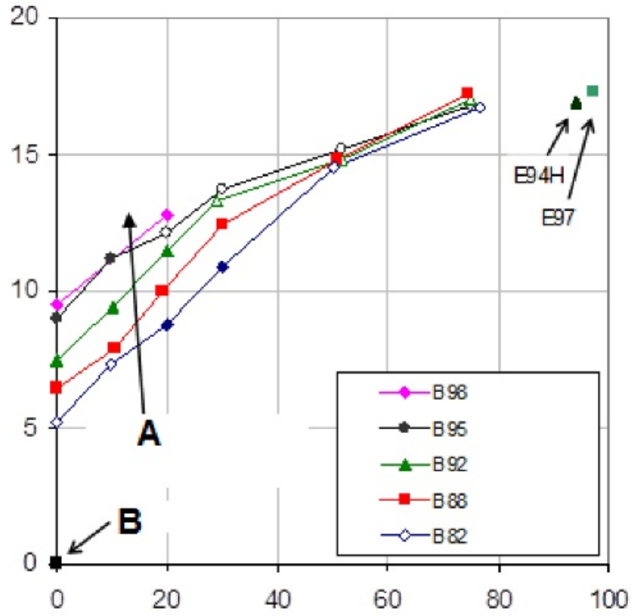
Key

X-axis ethanol % (*V/V*)

Y-axis RON)

Figure 2 — Ethanol boosting effects

With higher ethanol content, the current sensitivity between RON-MON of 10 points may be able to be relaxed for an E10+ petrol. As can be seen in Figure 3 [12], the sensitivity rises with increasing ethanol content. Nevertheless a sensitivity reduction shall be accompanied by very careful investigations of the MON effect on combustion phenomena (like low speed pre-ignition and high speed pre-ignition) that are particularly limiting the calibration freedom of downsized boosted engines.



Key

X-axis	ethanol % (*V/V*)	Y-axis	sensitivity (RON minus MON)
A	increasing aromatics, decreasing paraffins	B	iso-octane

Figure 3 — RON test sensitivity

RON is more important to describe the knock limitations and thus combustion efficiency of modern downsized boosted engines. RON – measured with an appropriately modified CFR engine for higher oxygenated fuel - correlates well with knock behaviour even at modern downsized turbo charged direct injection engines, at least for pure hydrocarbons or low ethanol blended petrol (<10 % (*V/V)* ethanol), but even for higher ethanol blends (>10 % (*V/V*)) as long as only moderately retarded combustion is applied (Centre of Combustion – CA50 approximately < 12 ° CA ATDC). Figure 4 presents an example of a MON/RON-correlation of 50 % heat release for combustion phasing optimum at 8°…10° CA ATDC [14].

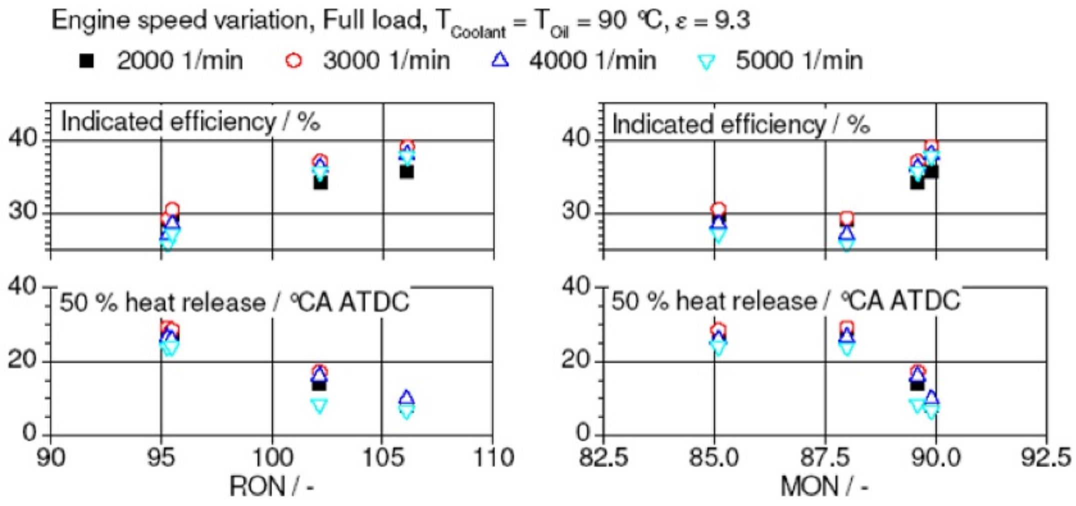


Figure 4 — Correlation of RON-MON with 50 % heat release at borderline detonation operation

So far, MON is believed to be the best available fuel parameter describing combustion phenomena such as low speed pre-ignition and high speed pre-ignition that particularly limit the calibration freedom of downsized boosted engines. However,for future higher boost engines– particularly in combination with more oxygenated fuel – new fuel characteristic describing parameters, which better describe pre-ignition combustion phenomena, shall be considered.

This issue of pre-ignition is therefore a very important issue for the future and more research into this issue is needed. In fact, MON (RON) may not be the best parameters for an E10+ petrol. 50 % heat release (combustion phasing) at borderline detonation operation (BLD) correlates well with RON, but not with MON (See Figure 5 [14]). Enrichment demand (in order to keep max. exhaust gas temperature limits) at borderline detonation operation (BLD) at a constant exhaust gas temperature correlates well with RON, but not with MON (see Figure 5).

For later combustion phasing even RON no longer describes the knock behaviour sufficiently. A high ethanol blended fuel with a high RON behaves differently in a modern highly boosted engine than a pure hydrocarbon fuel having the same RON.

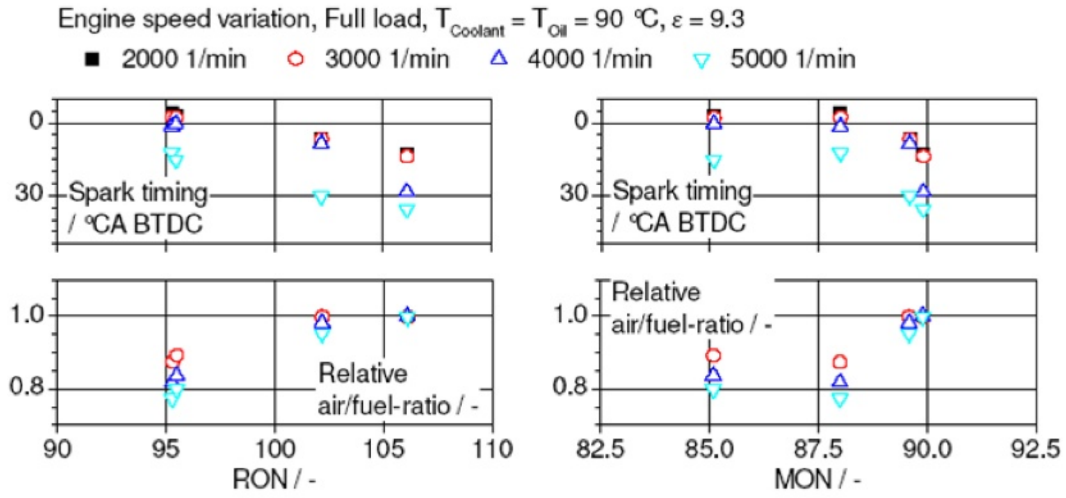


Figure 5 — Correlation of RON-MON with enrichment demand at the exhaust gas temperature limit and borderline detonation operation

7.4.2 RON-MON impact with higher oxygenates

Ethanol and other high heat of vaporisation (HoV) fuels result in substantial cooling of the fresh charge, especially in direct injection (DI) engines. The effect of charge cooling combined with the inherent high chemical octane of ethanol make it a very knock resistant fuel. Currently, the knock resistance of a fuel is characterised by the Research Octane Number (RON) and the Motor Octane Number (MON). However, the RON and MON tests use carburation for fuel metering and therefore do not replicate the effect of charge cooling in DI engines. Also, the operating conditions of the RON and MON tests also do not replicate the very retarded combustion phasing encountered with modern boosted DI engines operating at low-speed high-load.

In SAE Paper 2012-01-1277 [16] for a given petrol blendstock, increasing ethanol content significantly increased knock-limited performance with combustion phasing near the thermodynamic optimum, as is expected. However, due to ethanol's high sensitivity, knock-limited performance improved to a much greater extent with increasing ethanol content as combustion phasing was retarded. This effect was further enhanced by charge cooling with DI. Increasing ethanol content also significantly increased the knock-limited performance before enrichment was required to control exhaust gas temperature. The RON ratings of the fuels did not fully reflect the observed knock resistance of mid-to-high level ethanol blends (E20 and higher).

No more correlation between RON and knock limited engine efficiency at late combustion phasing (here significantly visible for CA50 > 12°ATDC). Therefore, a new parameter(s) (perhaps the sensitivity, maybe the ethanol content itself or a completely new parameter) needs to be evolved to describe the fuel [15] since, for knock limitation, RON-MON looks unlikely to be sufficient.

7.4.3 RON-MON needs for higher oxygenate-containing fuels

Need data to see what's needed and relationship of the delta for all future petrol engine concepts. Sensitivity of "S = RON-MON" may need to be changed for an E10+ petrol. It is well documented in the literature that MON is not correlated to engine efficiency on modern DI engines. It probably correlates better e.g. for old aircraft engines with preheated air supply.

Vehicle manufacturers design vehicles in order to exploit higher octane as per the legislation that shall guarantee the supply of such fuel. For example, with a RON of 106 vs. 98, a CO_2 gain of 5 % could be found on a mixed cycle of driving. Moreover, if vehicle manufacturers are sure of the higher RON value, energetic fuel consumption can be reduced by 40 % to 25 % particularly if driven on highway (i.e. effectively stabilised driving) due to a better knocking resistance (see CEN/TR 15993 [17]). The FVV study referred to in the figures above has indicated that a 3,1 % reduction in CO_2 and 2,5 % improvement in engine efficiency as measured on the NEDC have been achieved from an increase in compression ratio of 2,2 – enabled by E20 102RON petrol compared to a 95RON E0 petrol. Full load economy was improved up to 38 % at the same time. Higher loaded cycles like the WLTP will show significantly increased benefits. Furthermore the test engine (CR limited to 11,5) did not exploit the full potential. With improved base engine stiffness (Pmax-capability) and further increased Compression Ratio (CR = 13 - 14) further benefits can be expected.

Higher compression ration could see additional benefits (with stronger engine design perhaps limiting potential for engine downsizing).

In order to exploit the octane benefit a robust test method for RON/MON is to be accepted Europe wide or, even better, worldwide. This is currently not the case for fuels with an oxygen content above 4 % (*m/m*) (which is approximately 11 %vol ethanol). The accuracy of EN ISO 5163/EN ISO 5164 is limited above this limit.

For fuels with an ethanol content above 11 % (*V/V*), a new test method should be standardised. DIN 51756-7 [13] describes modifications of the CFR engine and is a good basis. However, it is only available in Germany and it does not provide any confirmed accuracy range for high oxygenated blends with RON > 100. Thus an international standard is needed and the accuracy of the method needs to be checked and confirmed in round robin tests.

Furthermore the apparent primary reference fuel (PRF) shortage for measuring octane performance > 100 RON (all containing lead) needs to be solved for Europe.

7.5 Driveability (volatility descriptors) for an E10+ petrol

7.5.1 General

Proper volatility of petrol is critical to the operation of spark-ignition engines with respect to both performance and emissions. Next, different volatility requirements for summer and winter and for different climatic conditions are to be considered. Volatility is characterised by two measurements - vapour pressure and distillation.

7.5.2 Vapour pressure

As in EN 228, vapour pressure of petrol should be controlled seasonally to allow for the differing volatility needs of vehicles at different temperatures. Likewise, the vapour pressure shall be tightly controlled at high temperatures to reduce the possibility of hot fuel handling problems, such as vapour lock or carbon canister overloading.

Control of vapour pressure at high temperatures is also important in the reduction of evaporative emissions.

At lower temperatures, higher vapour pressure is needed to allow ease of starting and good warm-up performance.

The relevance of the actual VP requirement needs to be compared with VP properties (measured) at higher temperatures all in relation to the volatility descriptors.

The right (new) parameters will need to be defined in an E10+ standard to deal with all such issues.

Further information on vapour pressure can be found in 8.2.1.2.

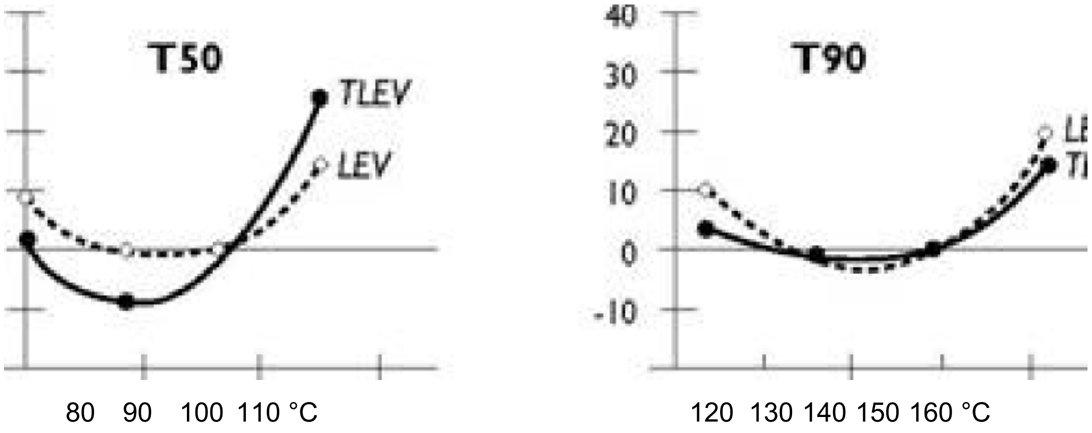
7.5.3 Distillation

Distillation of petrol yields either a set of ‘T’ points (T50 is the temperature at which 50 % of the petrol distils) or ‘E’ points (E100 is the percentage of a petrol distilled at 100 °).

Excessively high T50 (low E100) can lead to poor starting and warm-up performance at moderate ambient temperatures.

Control of the Distillation Index (DI), derived from T10, T50, T90, and oxygen content can also be used to ensure good cold start and warm-up performance.

Figure 6 [18] indicates that optimum values for T50 and T90 exist to achieve lower exhaust THC emissions.



Key

Y-axis Difference in THC (%)

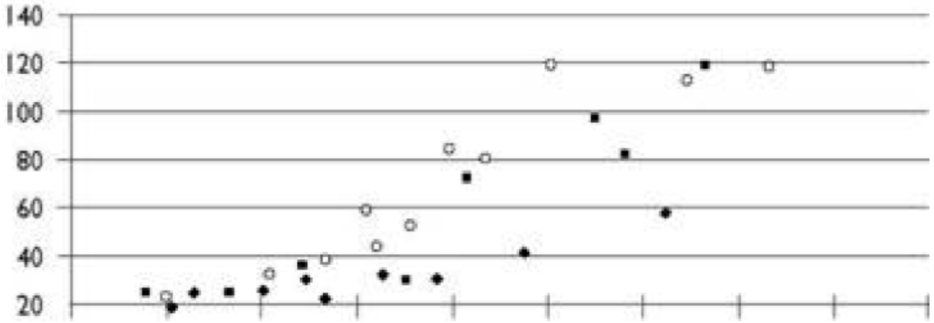
Figure 6 — Effect of T50/T90 on exhaust emissions comparison of LEV and TLEV

As shown in Figure 6, alternative descriptors for petrol distillation may be needed for E10+ petrol.

7.5.4 Other parameters/tests

- Hot weather driveability.
- Cold weather starting and driveability.
- Driveability concerns are measured as demerits.

Figure 7 [18] provides the test results from a recent CRC study which tested 29 test fuels: 9 samples all hydrocarbon, 11 samples with 10 % ethanol and 9 samples with 15 % MTBE. The data indicate that driveability problems increase for all fuel types as Driveability Index increases.



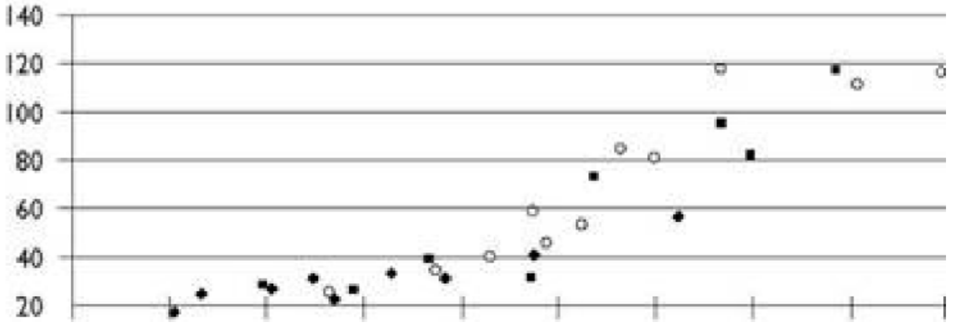
Key

♦	complete hydrocarbon (E0)	x-axis	oxygen content (% (*m/m*))
○	10 % (*V/V*) ethanol	y-axis	averaged weighted demerits
■	15 % (*V/V*) MTBE		

Figure 7 — Effect of Driveability Index on driveability

An oxygen correction factor is required to correct for higher driveability demerits for oxygenated fuels as compared to all-HC petrol.

Figure 8 [18] indicates how the correction factor smooth's the data presented in Figure 7.



Key

♦	complete hydrocarbon (E0)	x-axis	oxygen content (% (*m/m*))
○	10 % (*V/V*) ethanol	y-axis	averaged weighted demerits
■	15 % (*V/V*) MTBE		

Figure 8 — Oxygen corrected effect of Driveability Index on driveability

The DI is also directly related to tailpipe HC emissions. As with driveability demerits, HC emissions increase.

Other tests needed for complete customer acceptance of vehicle performance using an E10+ petrol?

Hot and cold weather vehicle driveability procedures also require updating to evaluate modern vehicles, especially those with active EMS, ABS, and 'drive by wire'.

7.6 Oxygenate compounds for an E10+ petrol

What are acceptable oxygenates? Ethanol, alcohols, ethers, etc. and how these oxygenates impact on emissions and vehicle compatibility.

Methanol is naturally present in industrially produced ethanol in small quantities, and can as oxygenate contribute to the combustion. However, methanol is toxic, it has a very high heat of vaporisation, it is strongly hydroscopic and contributes strongly to the formation of azeotrope and thus high vapour pressure, and it may require a co-solvent to prevent separation and can be aggressive towards certain metallic and non-metallic materials in the fuel systems. Thus its volume should be severely limited.

7.7 Other factors

The presence of trace contaminants originating from ethanol shall be addressed. Trace contaminants like phosphorus, inorganic chlorides or sulphates may affect the proper functioning and durability of exhaust after-treatment systems or may cause corrosion of the fuel system. EN 15376 is currently being revised to address these issues and possibly will need further revision when more information on will be available on their effects on future E10+ engine and after-treatment systems.

EN 228 prohibits the inclusion of phosphorus containing compounds (performance additives) in petrol in order to protect automotive catalyst systems from deactivation. Phosphorus is limited to 0,15 mg/l for the neat ethanol, following data presented by vehicle manufacturers describing the problem of achieving the exhaust emission limits. This new limit should be fit for purpose for an E10+ petrol with the next post-treatment generation, but this will require confirmation.

Inorganic chlorides are contaminants that are corrosive to metals even in low concentrations. Corrosion of stainless steel exhaust systems has been reported by vehicle manufacturers, who have also commented on problems of material corrosion in direct injection petrol engine fuel systems, as reported from fuel injection equipment manufacturers. The latter suggested that no more than 1 ppm of inorganic chloride should be allowed in the finished fuel. As the recommendation was that 1,5 mg/kg was possible for ethanol blended with petrol up to E85, the limit appears in the revised EN 15376 and EN 15492 [19] is the test method of choice.

Increasingly stringent regulations limit the amount of regulated pollutants that a motor vehicle may emit. Three-way catalysts are inhibited by the presence of sulphur oxides in the engine exhaust. This is presently under discussion and certainly an appropriate sulphate limit for an E10+ petrol shall be established in any standard.

Due to possible introduction of particulate filter on certain petrol engines (GDI) in the future and higher cell density catalysts, the need for low ash content limit for an E10+ petrol shall also be taken into account.

Impact of other unwanted impurities that may be identified is a last factor.

7.8 Possible studies

Optimum octane for a future fuel. The only available petrol for blending will be BOB, which meets EN 228 after addition of ethanol. The final RON/MON depended on the quality of the BOB (typical BOB RON could be down to 92). A study and full comprehension of the RON/MON possibilities for an E10+ petrol using ethanol or all other oxygenates is required.

Impact on vehicle compatibility, emissions, CO_2, trace contaminant, etc.

Pre-ignition and knock behaviour determination on future engine concepts, assessment whether RON-MON are suitable parameters for an E10+ petrol.

Existing industry standard procedures for evaluating hot and cold weather driveability performance may also need review and updating for future vehicle technologies.

8 Refinery, blender and logistics

8.1 Scope of current and future constraints and opportunities

In this chapter, current and future constraints and opportunities in the manufacture distribution and sale of Motor Petrol (Mogas) with increased biofuel contents were considered. A large amount of the information included in this section has been drawn from a report by CONCAWE [1].

The following areas are covered: Refining, Distribution Terminals, Blending Operations, Logistics and Service Stations. Some matters addressed are of a general nature as they are based on existing experience in the market based on the use of blends up to E10. Hence this clause covers fuels below and beyond E10.

For the purposes of this assessment only ethanol and ethers identified in the Fuels Quality Directive 98/70/EC [2], and subsequent amendments have been considered at higher levels with equivalent oxygen contents. A number of other oxygenates are identified in the Fuels Quality Directive but insufficient data are currently available on these materials at higher concentrations above 3,7 %(*m/m*) oxygen. It is recommended that these materials be subject to a detailed technical evaluation on a ‘as needs’ basis if there is evidence that they could be viable renewable blending components in the future. Oxygenates listed in the Fuels Quality Directive 98/70/EC and subsequent amendments: [2], [3], [4].

- Methanol
- Ethanol
- Iso-propyl alcohol
- Tert-butyl alcohol
- Iso-butyl alcohol
- Ethers containing 5 or more carbon atoms per molecule
- Other oxygenates – other mono-alcohols and ethers with a final boiling point no higher than that stated in EN 228.

It should also be noted that the Fuels Quality Directive will require amendment to allow higher biofuel blending above 3,7 %(*m/m*) oxygen content.

8.2 Refining related matters

8.2.1 Ethanol

8.2.1.1 General

The chemistry of ethanol is very different from that of hydrocarbon fuels. As a result, blending ethanol into hydrocarbon fuels introduces some specific challenges that shall be carefully addressed in the production, blending, distribution, and supply of mogas, including:

a) effect of ethanol on vapour pressure, octane rating, distillation, and related properties,

b) quality of the hydrocarbon blendstock for ethanol blending to ensure fit-for purpose mogas performance, and

c) tendency of ethanol to increase the dissolved water content of motor petrol.

8.2.1.2 Vapour pressure

Although ethanol has a lower molecular mass than most of the hydrocarbons used in motor petrol, ethanol is a liquid rather than a gas at ambient temperatures and pressures due to strong intermolecular hydrogen bonding interactions between ethanol molecules. These interactions are either very weak or absent in hydrocarbon mixtures. As a consequence, pure ethanol has a much lower vapour pressure (DVPE, 15 kPa – 20 kPa) than motor petrol. However, when ethanol is dissolved into a predominantly hydrocarbon mixture such as motor petrol, these same intermolecular interactions increase the volatility of the hydrocarbon-ethanol blend, most significantly at low concentrations of ethanol. For example, the maximum increase in DVPE occurs at an ethanol concentration of only about 1 % (*V/V*) up to 5 % (*V/V*) ethanol in a hydrocarbon blend. This positive deviation from ideal mixture behaviour (Raoult's Law) occurs because the intermolecular interactions between ethanol and hydrocarbon molecules are less than they are in the two pure liquids making it easier for molecules to volatilise from the ethanol-hydrocarbon mixture.

As shown in Figure 9 [1], addition of only about 2 % (*V/V*) of ethanol into petrol can increase the vapour pressure of the mixture by 6 kPa - 8 kPa. Further addition of ethanol above 10 % (*V/V*) results in a gradual reduction in vapour pressure.

The maximum vapour pressure increase depends on the ethanol content and temperature. For 37,8 °C the maximum is around E5, but for higher temperatures (100 °C, 130 °C) it is shifted to higher ethanol contents (E24).

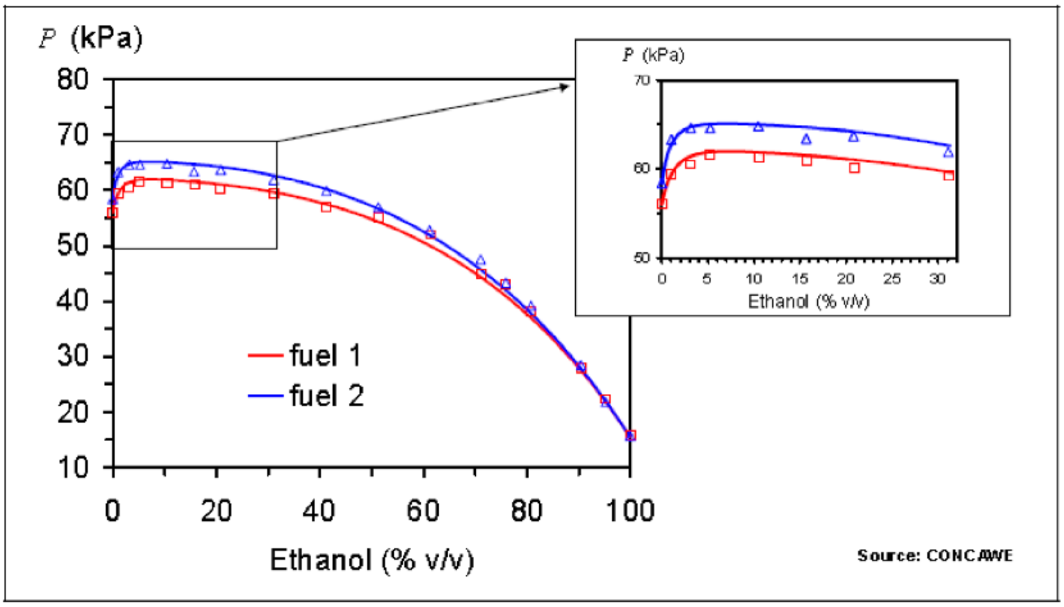


Figure 9 — DVPE of mixtures of petrol (95 MON) and ethanol

8.2.1.3 Distillation

In addition to its impact on vapour pressure, ethanol also changes the distillation characteristics of the petrol/ethanol mixture and the evaporated fraction at 70 °C (E70) is changed most significantly.

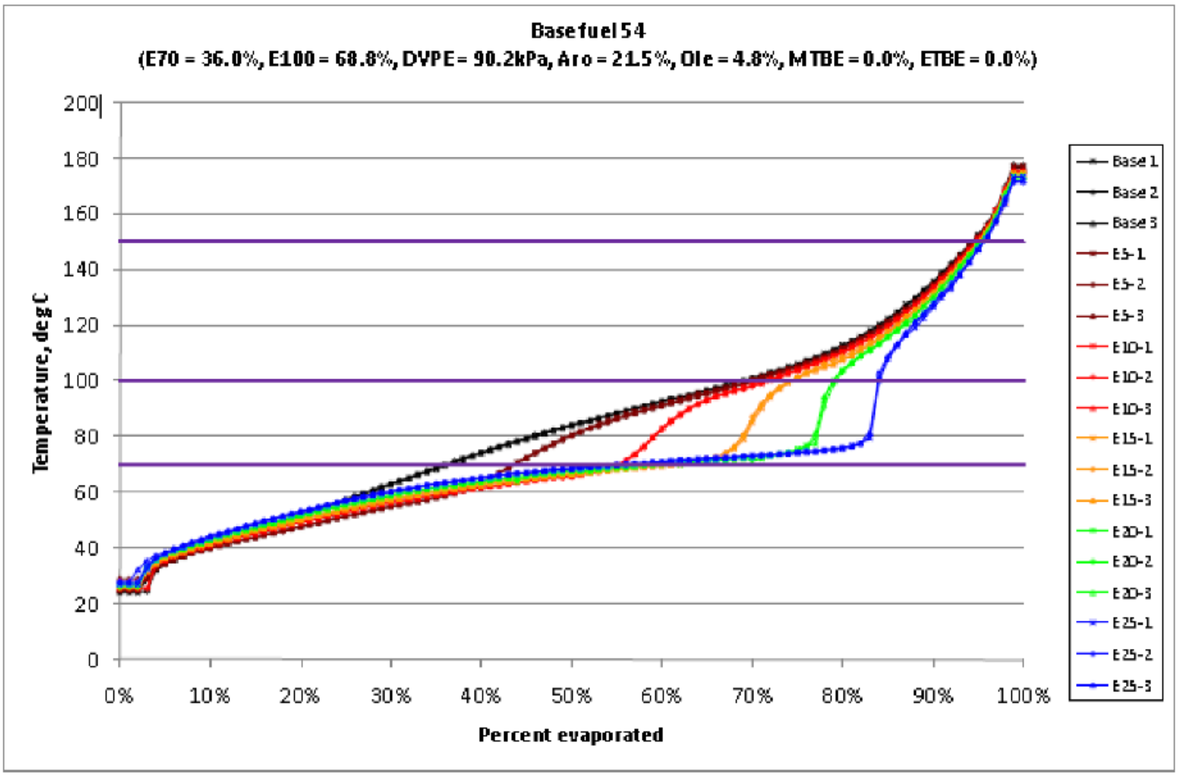


Figure 10 — Change in the % evaporated versus temperature for mogas as a function of the added ethanol content

As shown in Figure 10 [1], E70 increases by about 8 % (*V/V*) when 5 % (*V/V*) ethanol is blended into base petrol. An 18 % (*V/V*) increase in E70 is observed when 10 % (*V/V*) ethanol is blended into base petrol. These changes are significant and can be compared to the 28 % (*V/V*) overall range of E70 that is defined in the EN 228 specification for all volatility grades.

EXAMPLE For Class A mogas, the allowed E70 range is 22 % (*V/V*) to 50 % (*V/V*), or 28 % (*V/V*), in the EN 228 specification for E10.

New volatility descriptors will be required as E70 will no longer be suitable due to distillation curve distortion causing precision issues.

8.2.1.4 Octane requirements

Formula (1) can be used to estimate the “Blend-RON” and “Blend-MON” of petrol blended with ethanol based on the ethanol content and properties of the base and blended fuels.

$$ON_{g+a} = \frac{C_a}{100} \times I_a + \left(1 - \frac{C_a}{100}\right) \times ON_g \qquad (1)$$

where

ON_{g+a} is the blend octane number (Blend-RON or Blend-MON) of the petrol-ethanol mixture,

ON_g is the octane number (RON or MON) of the base petrol,

C_a is the ethanol content (% v/v), and Ia is the octane blending index of ethanol.

NOTE C_a and I_a are dependent variables.

The octane blending index of ethanol, *I*a, depends on the properties of the base motor petrol and the concentration C_a applied in the RON/MON test with the blended fuel. It should only be determined by preparing and measuring the properties of trial blends.

Since the octane of ethanol is higher than that of petrol, there will normally be a boost in both Research and Motor petrol octane after blending with ethanol.

8.2.1.5 Blend stock for Oxygenate Blending (BOB)

High ethanol blends will require the preparation of a special petrol blendstock with reduced vapour pressure modified distillation characteristics and reduced octane if current EN 228 specifications are to be met. As mentioned in 8.2.1.3 above, it is expected that new fuel volatility descriptors will be required to be developed.

A full review of the Well to Wheels (WTW) CO_2 emissions should be conducted to establish if octane levels are to be maintained or increased with higher oxygenate blends.

8.2.2 Ethers (ETBE and MTBE)

8.2.2.1 Vapour pressure

Unlike alcohols, ETBE has no azeotropic (non-ideal) effects on the vapour pressure of petrol. Therefore, ETBE blends at or near its true vapour pressure.

The blending Vapour Pressure (DVPE) of pure ETBE is 28kPa, well below that of finished petrol, thus allowing the use of more light hydrocarbons, typically butane during petrol blending.

The vapour pressure of pure ETBE (Calculated values from the Antoine Equation based on nonlinear curve fitting procedure) was measured by Petri Lindqvist in 1990and the results are shown in Figure 11 [22].

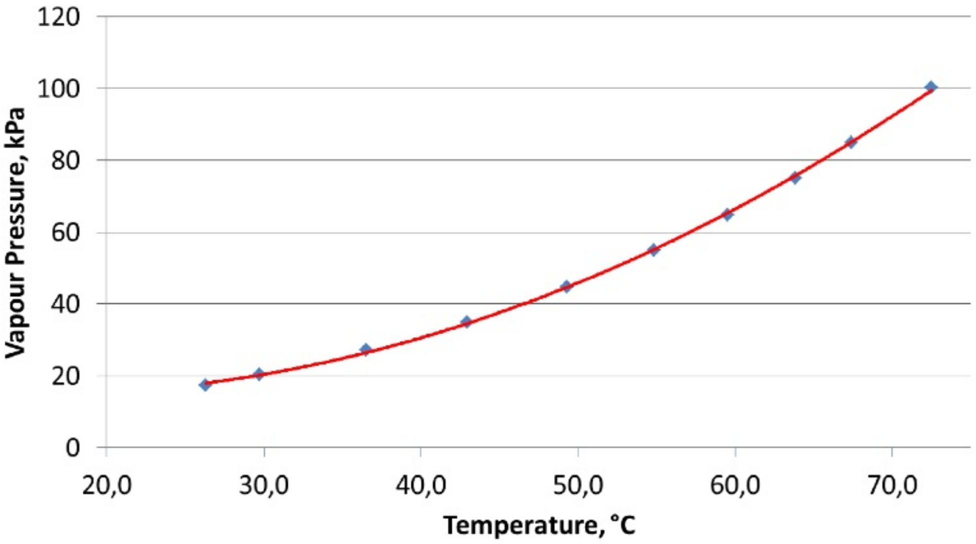
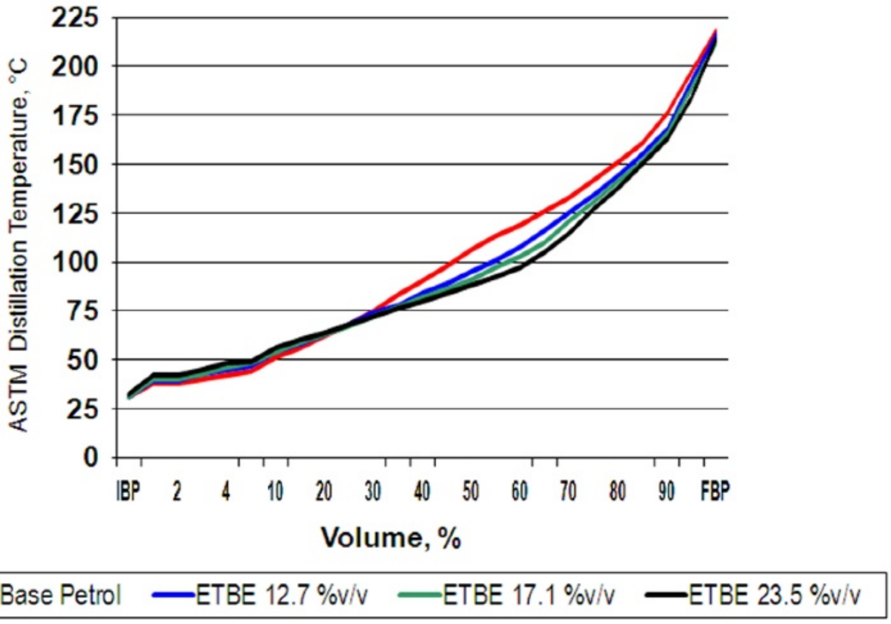


Figure 11 — Vapour pressure of ETBE

8.2.2.2 Distillation

Since ETBE and other ethers have no azeotropic effects on the distillation curve of petrol, ETBE blends into petrol in a smooth, predictable fashion much like any other hydrocarbon that boils in the same temperature range. Because of its boiling point (72 °C), ETBE will normally reduce the mid-range temperatures of the petrol's distillation curve. Figure 12 [23] shows that adding ETBE will significantly affect key distillation performance properties such as the T50 (temperature at 50 % volume distilled) and E100 (percent distilled or evaporated at 100 °C).



Key

X-axis	volume, %	Y-axis	ASTM Distillation temperature, °C
red line	base petrol	blue line	ETBE 12,7 % (*V/V*)
green line	ETBE 17,1 % (*V/V*)	black line	ETBE 23,5 % (*V/V*)

Figure 12 — Distillation of ETBE/mogas blends

8.2.2.3 Octane

Since the octane of ethanol is higher than that of petrol, there will normally be a boost in both Research and Motor petrol octane after blending with ethers.

Research has shown that addition of up to 20 % (*V/V*) MTBE has a linear effect in reducing the pre-ignition reactivity of the petrol [24].

8.3 Blending ethanol and ethers

8.3.1 General

IMPORTANT — Special precautions are required when blending ethanol whereas ethers can be blended at refineries as part of the normal blending process.

8.3.2 Refinery blending of ethanol

Blending ethanol at the refinery is not preferred because of problems that can occur with the subsequent transport and storage of the ethanol/petrol blend. Refinery blending may be appropriate, however, when ethanol/petrol blends are directly supplied to the loading rack from the refinery.

8.3.3 Terminal blending of ethanol

Direct blending at the loading rack is the best approach to overcome the transport and handling issues associated with ethanol-containing fuels. To do this, the refinery should produce a special BOB (see 3.1.4) and supply it to the terminal. This typically results in additional costs for injection equipment and ethanol storage, as well as an increase in truck movements.

For product quality reasons, terminals should be designated either as ethanol blending or ethanol-free locations (unless they have segregated systems for storage and handling) and their service should not routinely change.

Blending ethanol at low ambient temperatures is not believed to cause any additional problems that are not also encountered at higher ambient temperatures.

The commingling of ethanol and motor petrol can result in a small volumetric increase of the blend. This increase should be taken into account when considering product volumetric measurement and accounting.

8.4 Distribution and service station issues

8.4.1 Climatic conditions, seasonal grade management/changeover processes

New seasonal grade classifications will have to be established to ensure the correct operation of vehicles throughout the year and hence different climatic conditions. The process of seasonal grade changeover will require careful assessment and planning particularly with the potential for multiple mogas grades in the market if protection grade(s) are required to be maintained.

8.4.2 Water handling

8.4.2.1 Ethanol

Due to the presence of the hydroxyl (-OH) group, ethanol exhibits strong hydrogen bonding interactions, very similar to those found in liquid water. This effect means that ethanol is hydrophilic in nature and has a strong affinity for water. As a consequence, ethanol has a tendency to absorb water that may be present in distribution, storage, and vehicle fuel systems even when the ethanol is only present at low concentrations in petrol. This tendency means that extra precautions are required especially when ethanol is first introduced into the supply and distribution system and good housekeeping practices are needed thereafter following its first introduction.

The turbidity point, or haziness, is a good measure of the onset of phase separation as a function of the water content of the fuel blend. If excess water is present, ethanol can increase the concentration of dissolved water in petrol before phase separation (turbidity) is observed.

As shown in Figure 13, at the same turbidity point, the dissolved water content of petrol increases as the ethanol concentration in the blend increases.[25] The temperature of the petrol/ethanol blend is also a significant parameter. For example 15 % (*V/V*) ethanol containing mixture at 10 °C dissolves 1,0 % (*m/m*) water, the phase separation will occur at cold temperatures e.g. −20 °C since the dissolved water concentration of this mixture is only 0,7 % (*m/m*).

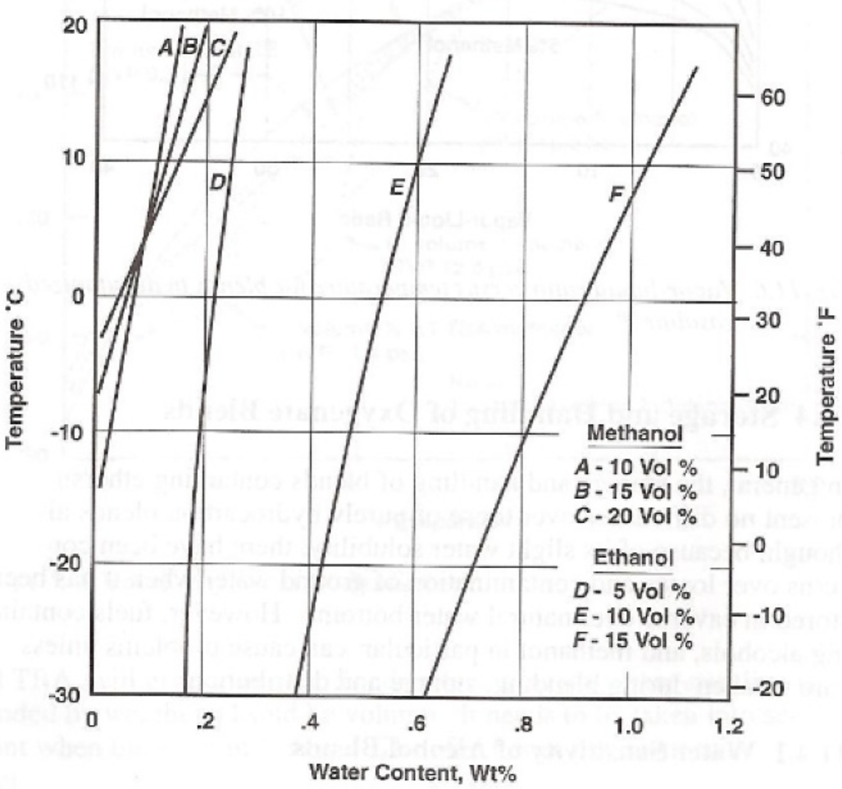


Figure 13 — Water tolerance of methanol and ethanol blends in petrol

In the worst case phase separation occurs. The petrol in the upper phase will usually contain less ethanol than does the lower phase and may be out of specification for other key properties, such as octane, vapour pressure, and distillation properties. Depending on the base fuel the composition of the phases will differ, making operability of vehicles difficult. .

If it is found that phase separation has occurred, all dispensers should be immediately deactivated and it is imperative that water bottoms are removed from the storage tank. The remaining hydrocarbon mixture should be tested to ensure that it is still in specification and, if not, appropriate action should be taken to remedy the situation. Since the water bottoms will contain some level of ethanol and hydrocarbons, this mixture may be flammable and appropriate precautions should be taken during handling and disposal, consistent with local safety and environmental regulations. Extra precautions are also needed to avoid water entering tanks. Tank cleaning, regular water checks and, if necessary, tank draining are advisable. It is also recommended that tanks are adequately dried before their first use. Terminal storage tanks should have fixed roofs with a floating internal cover In tank blending is not recommended unless water entry is properly controlled. When checking petrol storage tanks for water, ethanol-compatible water paste should be used in order to guarantee proper indication.

Because existing automatic water detection systems are disabled in the presence of ethanol-containing petrol, the use of ethanol in pipeline systems is not recommended without taking special precautions. Ethanol-containing petrol can also interfere with the protection offered by commonly used corrosion inhibitors in pipeline systems.

8.4.2.2 Ethers

ETBE has relatively low water solubility which allows the refiner to mix and handle ETBE petrol blends in much the same way as hydrocarbon-only petrols.

8.4.3 Housekeeping - Water management, tank draining, disposal of water drains and microbiological growth

For general housekeeping guidance see CEN/TR 15367-2 [26] and CEN/TR 15367−3 [27]. Increasing ethanol content results in improved water tolerance before the onset of phase separation as mentioned in 8.4.2.1. Good water management practices will continue to be required to ensure the finished petrol does not have excessively high water contents.

Bacteria can grow in aqueous solutions with ethanol, although when the level of ethanol dissolved in the water exceeds 15 % - 20 % it acts as a biocide and prevents microbiological growth. For an aqueous solution of ethanol to be formed in normal storage tank conditions phase separation would need to occur. If phase separation does occur the level of ethanol will be such that any microbiological growth will be inhibited. The main risk for microbiological activity is in the vapour phase where droplets of water can condense from humid air in the tank headspace and vapour recovery systems. This type of microbial activity results in the production of acetic acid and severe corrosion of metal surfaces exposed to the vapour phase. It is recommended that corrosion inhibitors are used in the ethanol to mitigate possible corrosion issues both in the liquid and vapour phases.

Ethanol can be difficult to remove from drains and waste water because it is very soluble in water. For this reason, the only way to efficiently remove ethanol is through biological treatment.

If the bacteria in treatment facilities have not been acclimatised to ethanol, much of the ethanol will pass through the treatment plant before it is degraded. Several weeks to a month may be required before a treatment plant can efficiently process ethanol-containing waste streams. Facilities can gradually increase the ethanol content in their waste water system as the bacteria become more efficient at degrading ethanol. It is important to test degradation performance in the laboratory and analyse the plant effluent for ethanol content over time in order to determine the degradation rate. Because terminals do not usually have biological treatment facilities, ethanol will most likely pass through the mechanical treatments that are commonly used. If the terminal sends its waste water to a municipal treatment plant, it is important to check with the treatment plant operators whether their facility can handle ethanol containing waste. In any case, the disposal of drain or waste water shall be done in accordance with all local regulations and permits.

8.4.4 Materials compatibility

8.4.4.1 Materials compatibility of ethanol

8.4.4.1.1 General

With respect to the compatibility with materials typically used in fuel supply and distribution systems, ethanol is different from fuel hydrocarbons in two important ways:

1) the presence of the polar hydroxyl (-OH) group, and

2) the relative size of the ethanol molecule[1].

Because of these differences, various components in the fuel distribution system may be less compatible with ethanol/petrol blends than they are with hydrocarbon-only fuels.

Many fuel system elastomers that have excellent compatibility with hydrocarbon-only fuels are themselves characterised by polar constituents. These constituents contribute to the stability of the elastomer through hydrogen-bonding and other interactions. These interactions may be vulnerable to substitution by the hydroxyl group of the ethanol. For this reason, some elastomers can lose their structural integrity over time due to the loss of stabilising hydrogen bonding interactions when the elastomer is exposed to ethanol/petrol blends. Ethanol can also extract plasticisers in the elastomers, reducing the flexibility and toughness of the elastomer

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[1] Methanol is an even smaller molecule, but is not covered in this technical report.

products. Fuel system components such as seals, gaskets and piping that are made from polymers and elastomers shall be designed to retain their structural integrity, strength and flexibility after extended exposure to ethanol/petrol blends.

Because ethanol is a smaller and more polar molecule than MTBE, ETBE and other oxygenates, there is a lower energetic barrier for ethanol diffusing into and through elastomeric materials. Over time, ethanol can accumulate in some of these materials, causing them to swell and soften, leading to an overall weakening of the elastomeric structure. This effect is obviously more problematic as the ethanol content increases.

Next to phase separation phenomena (see also 8.4.1) and the related electrochemical corrosion (also called wet corrosion especially occurring in low blends) ethanol blends in general can also cause alcoholate corrosion (alkoxide corrosion, dry corrosion) or pitting of aluminium fuel line materials at elevated temperatures closer to the engine [65,66].

In comparison to hydrocarbons, ethanol contains an hydroxyl functionality. This can contribute to corrosion and wear problems of some metal components. The tendency of ethanol to loosen varnish and gum deposits can also have a significant impact. By loosening these deposits, ethanol may accelerate wear of metallic components that are in regular contact with fuel by scouring internal surfaces with suspended particles. The use of corrosion inhibitors can help mitigate this problem although the compatibility of these additives with ethanol/petrol blends shall be thoroughly evaluated.

Corrosion inhibitors are not effective, however, in controlling vapour phase corrosion. This is a major problem in tank ullage spaces due to the combination of ethanol vapour with vapours from other oxygenates plus humid air leading to the formation of acids and aldehydes which are aggressive to both metals and non-metallic materials.

It is important to ensure that compatibility studies include tests on the vapour phase, not just the liquid phase.

API has found [28] that experiences related to the use, handling and storage of fuel-grade ethanol and recent unpublished studies indicate real concerns regarding the phenomenon of stress corrosion cracking (SCC) of carbon steel tanks, vessels, piping and associated equipment in fuel ethanol service. It appears that this situation has already had an impact on commercial operations. Even though only limited references to SCC of steel in ethanol have been found in the published literature, documented failures of equipment in user's storage and transportation facilities have dated back to the early 1990s. The literature provides information on the influence of various parameters on ethanol corrosivity. The major factors identified from this survey include: water content, pHe, sulfate and chloride concentration, temperature, electrochemical potential, and use of inhibitors.

Studies to find the effects of various impurities in fuel ethanol on SCC found that SCC of carbon steel can occur in denatured ethanol meeting ASTM D4806 specification [29]. Following Brazilian experience, SCC appears not to occur at medium and high level ethanol fuel blends, but this has not been studied in depth. In addition to water, the most statistically important factor that caused SCC appear to be dissolved oxygen.

Soft metals such as copper, zinc, brass, bronze, lead or aluminium should be avoided for operational components as ethanol can leach material from these, contaminating the fuel system. Stainless steel is recommended.

Non-metallic materials such as natural rubber, urethane, polyurethane, cork (gaskets), polyester-bonded fibreglass laminates, PVC, polyamides, polyethylene, and methyl-methacrylate plastics are weakened and degraded by ethanol leading to fuel permeation. Recommended materials include Buna-N, polychloroprene, fluorosilicone, nylon, polypropylene, nitrile, polysulfide rubber, Viton, ptfe-coated Viton, and Polytetrafluoroethylene (PTFE).

NOTE As methanol is more corrosive than ethanol, components and materials certified as compatible with methanol will almost always be acceptable for use with ethanol.

Tables 1 and 2 provide an overview of materials that are either recommended for use or should be avoided when handling and distributing ethanol or ethanol/petrol blends. These list are not comprehensive and the quality of the material should be appropriate for the intended application. It is strongly advised that the manufacturers of these products are consulted before ethanol or ethanol/petrol blends are introduced.

8.4.4.1.2 Tanks

Both above-ground and under-ground tanks should be constructed of low carbon, cold-finished steel and be butt-welded. Plated metal should not be used. Fibreglass tanks can be used, but should be lined to prevent the fuel contacting the fibreglass. Viton should be used in, e.g. drop tube seals.

8.4.4.1.3 Gaskets

Fuel dispensers may contain between 20 to 60, or even more, gaskets and seals. These can be made of a wide variety of materials. Exposure to ethanol/petrol blends may cause gaskets and seal materials to swell, possibly resulting in increased permeability. It is therefore essential that all gasket and seal materials used in all dispensing, but also terminal, equipment designed to operate with E10+ mogas, should be certified as being compatible.

8.4.4.1.4 Pumps

Preferred sealing materials are carbon, ceramics and Polytetrafluoroethylene (PTFE) for packing construction.

8.4.4.1.5 Pipes

Viton and fluoro-elastomers are satisfactory. Also polyethylene. Avoid zinc-plated steel.

Table 1 — Recommendations for materials in fuel distribution systems considered for use in ethanol and blend applications with petrol

Material	Recommended	Not recommended
Metals	Carbon steel with post-weld heat treatment of carbon steel piping and internal lining of carbon steel tanks Stainless steel Bronze Aluminium	Zinc and galvanised materials Brass Copper Lead/tin coated steel Aluminium (possibly an issue for E100)
Elastomers	Nitrilic butadiene rubber (e.g. BUNA N) (hoses and gaskets) Fluoroelastomers (e.g. Fluorel, Viton) Polysulfide rubber Fluorosilicone Chorobutyl rubber (e.g. Polychloroprene)	Nitrilic butadiene rubber (e.g. BUNA N), seals only Polychloroprene (seals only) Urethane rubber Acrylonitrile-butadiene hoses Polybutene terephthalate
Polymers	Acetal Polypropylene Polyethylene Polytetrafluoroethylene (PTFE) Fibreglass-reinforced plastic	Polyurethane Polymers containing alcohol groups (such as alcohol based pipe dope) Polyamide (e.g. Nylon 66) Fibreglass-reinforced polyester and epoxy resins Shellac
Others	Paper Leather	Cork

8.4.4.1.6 Pipe sealants

Polytetrafluoroethylene (PTFE) tape is the best sealant material. Avoid alcohol-based materials.

8.4.4.1.7 Metres

Calibration can be affected by the effect of ethanol on seals, so metres should be re-calibrated from time to time to ensure it is not over-dispensing.

8.4.4.1.8 Filters

Filters should be checked periodically as ethanol/blends can pick up tank sediments and lacquers.

8.4.4.1.9 Dispensers

See also 8.5.4.1.3. Recommended metals in the fuel path are iron unplated steel or stainless steel. Vane pump impellers should be of steel or high chemical resistance polymers. Avoid soft metals such as copper, zinc, brass, lead or aluminium.

8.4.4.1.10 Hoses

Standard nylon lined hoses are not generally considered to be at risk. Vapour recovery may impose particular requirements.

Table 2 — Compatibility of ethanol with materials commonly used in fuel distribution systems

Item	Recommended	Not recommended
Containment system (around tank and loading racks)		Clay liners. Ethanol may dry out the liner and allow cracks to develop
Tanks used for E5	Mild steel Fibreglass-reinforced plastic (newer types)	Some lining materials commonly used to prevent small leaks such as older types of epoxy or polyester resin-based materials. If a tank is relined, the manufacturer should be contacted for advice.
Tanks used for E100	May require a tank constructed of a special chemical resin	
Pumps used for E100	Carbon and ceramic seals Polytetrafluoroethylene (PTFE)-impregnated packing materials	
Pipe sealants used for E5 and E100	Polytetrafluoroethylene (PTFE) tape	Alcohol based pipe sealants
Meters used for E5	When first converting to ethanol/gasoline blends, it is advisable to recalibrate meters after 10 to 14 days to ensure that the fuel change has not caused any meters to over-dispense.	
Meters used for E100	Internal O-rings and seals should be selected that are specifically designed for use with ethanol.	
Fuel Filters for E5	It may be necessary to change the fuel filter shortly after converting to ethanol/gasoline blends. Once the dispensed fuel is clear and bright, the filter life should be similar to those in regular gasoline applications.	Ethanol can dissolve the glue in filter elements that are not specifically designed for this service. Filters containing shellac
Hoses used for E5	No problems reported	
Hoses used for E100	Contact the manufacturer	
Nozzles used for E5	No problems reported	

[a] For this table, the term ‘E100’ refers to pure or denatured ethanol and the term ‘E5’ refers to blends of motor gasoline containing up to 5 % (*V/V*) ethanol (EN 228).

8.4.4.1.11 Nozzles

Not generally considered to be at risk, although operation on high ethanol-content blends (e.g. E85 and E100) suggests that aluminium / aluminium alloy nozzles should be used with caution. Nickel-plated nozzles have been recommended for these higher blends.

8.4.4.1.12 Separators

e.g. Class 1 separators to contain fuel tanker spillages on forecourts and prevent entry to drainage system. EN 858 (all parts) [30]). Glass Reinforced Plastic (GRP) tank and seals need to be ethanol resistant.

8.4.4.1.13 Temperature probes

Use stainless steel sheathing.

8.4.4.1.14 Fittings and connectors

Stainless steel is considered the best material, or black iron. If aluminium or brass fittings are used they should be nickel-plated. Bronze can be problematical because of its copper content.

8.4.4.1.15 Other issues on materials compatibility of ethanol

Care should also be taken to ensure the ethanol (liquid and vapour) compatibilities of other fuel handling equipment such as tank probes, drop tubes, overfill prevention devices, tank lining systems, sump pumps, etc.

Please note that Tables 1 and 2 are not presenting a totally comprehensive listing. It is nevertheless intended to prompt careful consideration of ethanol / petrol compatibilities wherever such fuels are to be handled.

8.4.4.2 Materials compatibility for ethers

8.4.4.2.1 General

Ethers have been used in petrol for some 30 years. In a 1999 literature review commissioned by the State Water Resources Control Board's Advisory Panel of California it was concluded that there are no documented material compatibility issues for retail stations dispensing reformulated fuels containing ethers up to 15 % (*V/V*) MTBE. It was also postulated that ETBE would provide directionally improved compatibility and permeability to MTBE. This is consistent with the 1993 Dupont product bulletin “Leak Prevention of Reformulated Fuels and Oxygenates” which concludes based on swell testing that “ETBE is the least aggressive ether oxygenate towards elastomeric materials”.

Actual test results [31] are given in the following subclauses.

8.4.4.2.2 Swell tests

These were carried out by immersing small pieces of the material in each of the 6 fuels for a period of 168 d. They were removed periodically and weighed in air and in water to determine volume changes. All test samples were duplicated in separate containers of fuel. Little differences are seen between ETBE and the base fuels. Figure 14 presents an overview of the results. The most difference being with the high aromatic ASTM “C” blend on the N-butyl “O” ring. Replacement of 5 % ETBE with ethanol was a little harder on the elastomers in the carburetor pump diaphragm, the N-butyl “O” ring and urethane.

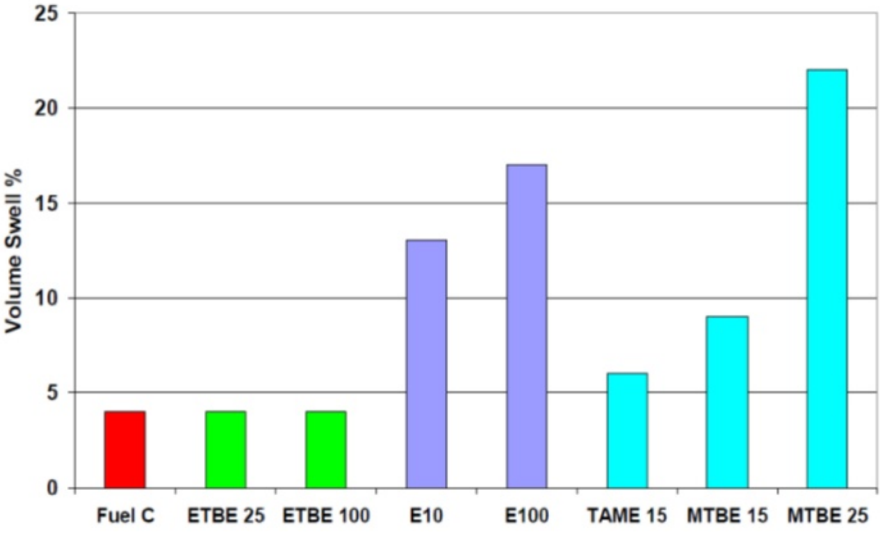


Figure 14 — Fluoroelastomer in petrol and neat oxygenates volume swell after 168 h at 23 °C

Table 3 shows the effect of different ether volume content on seal swell

Table 3 — Ether volume swell percentage after 30 days at 24 °C

Elastomers	Fuels			
	Premium Gasoline	+ 13% MTBE	+ 13% ETBE	100% ETBE
NEOPRENE polychloroprene	54	58	50	27
CHEM RAZ perfluoroelastomer	26	29	26	22
BUNA N (nitrile rubber)	25	28	26	13
Poly - urethane	21	22	21	19
HYDRIN 200 epichlorohydrin	13	12	12	6
VITON A fluoroelastomer	3	11	7	8
Poly vinyl chloride (PVC)	1,6	0,9	1	0,7
DELDRIN polyacetal	0,7	1	0,9	0,5
Fiberglass (FRP)	0,4	0,4	0,3	-0,1
NYLON 6/6	0,1	0,5	-0,4	-0,4

8.4.4.2.3 Permeability tests

Duplicate one foot lengths of fuel dispenser hose, hydraulic hose and polychloroprene fuel line were filled with the same fuels used in the swell tests. These were stored over a period of 168 d at room temperature, and periodically weighed to determine fuel loss. At least for a period of 60 d, all ETBE blends fall between the premium fuel and ASTM “C”. The 100 percent ETBE in the fuel line do not show as smooth a curve beyond

60 d as expected and could be due to weighing error. This implies no more problems would encountered than with a normal petrol.

8.4.5 Vapour recovery systems

Compatibility of current technology vapour recovery systems is a concern with higher oxygenate levels. A thorough investigation would be required to assess the impact of higher ethanol and ether blending on the operation of these systems in distribution terminals and service stations.

8.5 Logistics

8.5.1 Transport of ethanol and oxygenate blends

8.5.1.1 General

Ether and other oxygenate blends may be treated as conventional petrol blends in general. No additional precautions are required.

8.5.1.2 Transport via multi-product pipelines

A review of current pipeline practices in other parts of the world indicates that the pipeline shipment of ethanol/petrol blends is not common practice. Pipeline operating companies in the USA, for example, prohibit the shipment of ethanol/petrol blends. If pipelines are to be used for this purpose, they shall be completely dehydrated prior to the shipment of ethanol/petrol blends because of the affinity of ethanol for residual water. Dehydrating a pipeline system is a major and potentially costly endeavour and will require additional filtration and/or coalescer equipment to be successfully completed.

If ethanol is transported via a pipeline system, more frequent cleaning and inspection should occur due to the capacity of ethanol to pick-up dirt (rust, sediments, etc.) throughout the system. Corrosion inhibitors that are compatible with ethanol should be selected. In multi-product pipelines, the potential contamination of jet fuel by ethanol is a very serious concern. Because of the affinity of ethanol for water, higher concentrations of dissolved water can be carried through the pipeline system and jet fuel filter/coalescer performance may be impaired. On the other hand, in South Africa, two trial shipments of ethanol/petrol blends were carried out in multi-product pipelines, without reported deterioration of the jet fuel quality.

Although the use of pipelines to transport ethanol/petrol blends may not be excluded, significant capital investments will be required to guarantee a completely dry system, including additional filtration equipment, suitable buffers, interface management and quality monitoring systems.

Prior to granting approval for such pipeline shipments, large scale trials should be carried out with the active participation of all stakeholders, including the pipeline operators, oil companies, aviation companies, and OEMs.

8.5.1.3 Transport by road and rail

In principle, the distribution of ethanol/petrol blends by road truck and rail is done in the same way as conventional motor petrol. However, special precautions should be taken to avoid contamination of the ethanol/petrol blend with water, dirt, rust, and gum. In particular, the ethanol/petrol blend should not be mixed with hydrocarbon-only fuel in order to avoid increases in vapour pressure.

The transport of high Ethanol content blends may require switching away from aluminium tank trucks to more compatible materials or lining the tank with a suitable protective layer.

8.5.1.4 Transport by barge

Due to the affinity of ethanol for water, the transport of ethanol/petrol blends by barge should be avoided. If this is not possible, then extra precautions and procedures should be put in place to ensure safety, cleanliness, and product integrity following transport. In particular, vessels that occasionally use product tanks as ballast water tanks should not be used for transporting ethanol/petrol blends. Any commingling of ethanol/petrol blends and water should be strictly avoided.

8.5.2 Co-mingling of different grades in terminals, service stations and vehicles

Precautions will be required to minimise the number of grades of petrol with different oxygenate types and contents in both the distribution logistics and the service stations to avoid co-mingling and cross contamination issues resulting in off-grade product.

8.5.3 Management of off-grade product

Unlike conventional petrol it is not possible to return highly oxygenated fuels to the refinery for reprocessing as they can disable the crude salt driers and seriously affect the performance of the waste oil recovery systems. Returning off-grade product to terminal tanks is also very difficult to manage particularly in the case of ethanol blends where rack blending is in place. It is recommended that alternative disposal routes are established for managing off-grade product such as incineration or separate reprocessing.

8.5.4 Number of Mogas grades

It is recommended that the number of fuel grades should be minimised to simplify customer choices and avoid miss-fuelling and facilitate logistics. Appropriate protection grades will be required going forward to protect the historic vehicle fleet that is compatible with E10 fuels.

8.6 Safety and fire fighting measures

8.6.1 Safe handling

Safety precautions and equipment for storing and handling ethanol/petrol blends are similar to those used for conventional petrol. Protective equipment including gloves should always be worn. Skin exposed to fuel should be washed with soapy water. The relevant Safety Data Sheet (SDS) should also be reviewed for recommendations on safe handling, type of gloves, and related procedures before beginning work with ethanol and with ethanol/petrol blends.

8.6.2 Surface spills and leaks

Spills and underground leaks of ethanol/petrol blends and ether/petrol blends should be treated in the same manner as motor petrol spills and leaks, including notification of the proper authorities. The supplier’s SDS should also be reviewed for recommendations on spill clean-up procedures.

8.6.3 Fire protection and fire-fighting agents for fires involving ethanol/petrol blends

Personnel should approach an ethanol/petrol or ether/petrol blend fire with the same caution as they would use in approaching a conventional petrol fire, and similar fire-fighting techniques should be used. The use of alcohol resistant foams is required when fighting fires involving fuels containing high levels of ethanol. For fighting fires involving petrol containing up to 10 % (*V/V*) ethanol, such foams may not be required but it is strongly advised that responsible personnel review their specific operations and use appropriate equipment based on local safety recommendations and requirements.

Fires involving pure ethanol do not produce smoke and the flames are difficult to see in daylight.

8.6.4 Storage

Ethanol can be stored in fixed roof tanks with or without an internal floating cover. Tanks with external floating covers can allow some rain water to enter the tank and are not recommended for storing ethanol.

The vapour concentration above pure ethanol will be in the flammable range when the liquid temperature is between about 12 °C and 43 °C. Because impurities in the ethanol can alter this range, however, it is good engineering practice to assume that the vapour phase above fuel-grade ethanol is always in the flammable range and procedures and equipment should be used that ensure safe storage conditions.

The type of vent on a fixed roof tank will not greatly affect the average flammability condition whether the vents are open or Pressure/Vacuum (P/V) vents. (A P/V vent is a venting device that reduces the free flow of air and vapours in and out of the tank).

When used for storing pure ethanol, an internal floating roof tank with a P/V vent on the fixed roof is likely to be in the flammable range. An IFC with air scoops (that is, with slits in the tank walls to allow free venting, conforming to API 650H guidelines where permitted) will probably be outside of the flammable range as long as the floating roof seals are in good condition and the number and size of the vents are appropriate.

For this reason, procedures, similar to those used for petrol storage, should be used to ensure against ignition, especially when fixed roof tanks are used to store liquid ethanol. These procedures can include the use of inerting gas systems to avoid a flammable mixture in the vapour space although this approach may not be practical in all situations. Ethanol and blended fuel storage shall comply with prevailing legislation.

8.6.5 Sources of ignition

The presence of ethanol does not substantially increase the risk of static electricity since ethanol has a high electrical conductivity. Lightning could be a problem but a well-grounded metal tank with a well maintained P/V vent or flame arrestor on the vent is considered safe. Excessive friction could cause ignition inside an internal floating roof tank if, for example, the floating roof were to develop a mechanical problem.

Obviously, hot repair work or other human activities near the open vent of an in-service tank shall be avoided because these practices could cause ignition to occur.

Procedures, similar to those used for conventional petrol tanks, should be in place to avoid these problems.

The effect of higher levels of ethanol and ether on flammability limits will need to be evaluated to ensure that the risk of static ignitions are avoided during the switch loading of diesel to ensure appropriate precautions are in place.

8.7 Regulatory requirements

The following is a list of additional regulatory requirements that will need to checked and may require legislative changes to facilitate the manufacture, distribution and sale of high oxygenate motor petrol blends.

- Zoning/Planning requirements
- Storage regulations
- Permitting
- Emergency response procedures
- Local customs requirements
- Denaturing of ethanol

9 Test methods

9.1 Introduction

This clause discusses the applicability of test methods for E10+. In order to limit the scope towards combinations and levels of oxygenates this clause focusses on petrol with a nominal ethanol content between 10 % (*V/V*) and 25 % (*V/V*). This focus is chosen as once the ethanol is higher than approximately 20 % to 25 % (depending on the vehicle) more engine and vehicle measures would likely be needed. Firstly the parameters currently applied for EN 228 fuels (including E10) are considered. Next, potential new parameters are taken into account. Besides the applicability, also an estimate for the required time and effort for the assessment is given.

Each specified or limited fuel property shall be measurable by one or more test method(s) which has/have been verified to produce satisfactory analytical results for the envisaged product type as well as for the expected levels of the property under investigation.

This means that each such method shall have been verified to be fit for purpose by the responsible analytical test method group(s), for the following aspects:

— applicable to the envisaged product type / product family;

— applicable measurement range for the intended property levels;

— satisfactory precision / measurement uncertainty, i.e. sufficient repeatability and reproducibility according the rules of EN ISO 4259 [32].

This verification of test method applicability could be accomplished in two steps:

1) a preliminary estimate from the test method experts, based on the experts' laboratory and field experience, and

2) proof and confirmation for this preliminary estimate by appropriate inter-laboratory studies.

Properties for which no such test methodology exists, cannot be considered seriously in any fuel specification, until a suitable test method with acceptable performance has indeed been developed, tested and verified.

NOTE The time required for method revision does not take into account the potential increasing variability of the blend stocks.

9.2 Current petrol fuel requirements

9.2.1 General

As a starting point, the parameters and test methods, currently applied in EN 228, were checked for their applicability for E10+ fuels.

9.2.2 Sulfur

9.2.2.1 General

In the current EN 228, the following standards are identified to determine the total sulfur content: EN ISO 20846 (UVF [33]) and EN ISO 20884 (WDXRF [34]). Besides UVF and WDXRF, ICP-AES is conceivable for sulfur measurement.

9.2.2.2 EN ISO 20846

This standard specifies a UVF (ultraviolet fluorescence) test method for the determination of the sulfur content of motor petrols containing up to 3,7 % (*m/m*) oxygen, including those blended with ethanol up to about 10 % (*V/V*), having sulfur contents in the range 3 mg/kg to 500 mg/kg. The UVF would not be affected by the presence of different levels of oxygen containing species. Some quick tests would have to be done to check the precision data when broadening the scope to E10+. The time needed to realise those tests would be close to one month.

9.2.2.3 EN ISO 20884

This standard specifies a WDXRF (wavelength-dispersive X-ray fluorescence) test method for the determination of the sulfur content of liquid, homogeneous automotive fuels from 5 mg/kg to 500 mg/kg, which have a maximum oxygen content of 3,7 % (*m/m*). This product range covers motor petrols containing up to about 10 % (*V/V*) ethanol. Previous studies made by CEN/TC 19 have shown that the quantification of sulfur content by WDRXF could be affected by the presence of oxygen depending on its level. Tests were made with oxygen content up to about 3,7 % (*m/m*). At that level, the oxygen effect would correspond to about 0,6 mg/kg sulfur. This bias is lower than the repeatability of the method. Nevertheless, it would be necessary to run some measurements to check the applicability of this technique to E10+ and to evaluate the impact on the precision data. Moreover, the interference with oxygenates (not only ethanol) shall be checked. The time needed to realise those tests would be close to two months.

To run WDXRF measurement, it would be necessary to know the total oxygen content of each sample before measuring its sulfur content. The use of calibration samples with fixed ethanol (or known oxygen content from other sources) content could be a way of solving matrix effects.

9.2.2.4 ICP-AES

The ICP-AES can also be used to measure sulfur but some previous works have shown that this technique is not easy to run on petrol samples due to their volatility. Moreover, CEN/TC 19/WG 27 was requested to develop a method to determine phosphorus and sulfur contents in FAME by ICP-AES. Both ruggedness study and round robin test have led to the same conclusion: the method was not robust enough to measure low sulfur content and it has been decided to remove sulfur from the scope (the method is dedicated to phosphorus only). This shall be taken into account for E10+ too.

9.2.3 Manganese

In the Fuels Quality Directive, manganese in fuels is limited (i.e. 6,0 mg/L until 2013-12-31, and 2,0 mg/L from 2014 to 01-01 onwards). This limit would also apply for E10+ fuels. The current test methods (i.e. EN 16135 [35] and EN 16136 [36]) are applicable for E10 but need to be re-assessed for E10+ fuels. This assessment needs approximately 5 months, excluding the time needed to revise the test method standard.

9.2.4 Lead

EN 228 specifies that the lead content shall be determined by applying EN 237 [37]. This standard describes an AAS (atomic absorption spectrometry) test method for the determination of the lead content of petrol in the range 2,5 mg/L to 10,0 mg/L. This test method would not be affected by the oxygen content of the petrol sample. Nevertheless, the possible impact of the impurities from the oxygenated compounds will have to be verified.

Some quick tests on E10+ samples shall be run to confirm that statement. The volatility of the E10+ samples could be problematic depending on the amount of ethanol. This point would have to be checked too. The time needed to realise those tests would be close to two months.

9.2.5 RON/MON

The levels for RON and MON for E10+ are not defined yet.

The octane quality of petrol is expressed by its research octane number (RON) and motor octane number (MON). The test methods for RON and MON are described in EN ISO 5164 [10] and EN ISO 5163 [9] respectively. The working range is 40 to 120. For ratings above 103, primary reference fuel (PRF) blends with tetraethyl lead (TEL) are needed. The use of TEL containing PRFs should be avoided when rating petrol on the same test engine. Therefore the working range is practically 40 to 103.

According to the scope, these International Standards can be used for oxygenate-containing fuels containing up to 4,0 % (*m/m*) oxygen. The method should be fine-tuned and checked for mixtures higher than 25 % ethanol.

ASTM D02, Subcommittee 1, has set-up a TF to verify the applicability of the equivalent ASTM test methods (i.e. ASTM D2700 [39] for MON and ASTM D2699 [38] for RON) on high ethanol fuels (samples containing up to 25 % ethanol). Initials results showed that no equipment changes or modification were necessary for these fuel samples, and that the results gave indications of method equivalence. The inclusion of these types of fuels into the test ASTM test methods' scope by simple revision should also be initiated for the respective ISO methods.

9.2.6 Density

The density can be measured by the hydrometer method (EN ISO 3675 [40]) or the digital density metre method (EN ISO 12185 [41]). Based on a European study on ethanol/petrol blends [42] the possible densities of E10+ are in the range between 710 kg/m^3 and 790 kg/m^3. However, the densities of E20 market fuels (source: SGS WWFUEL Survey) are more in the range between 720 kg/m^3 and 790 kg/m^3. These ranges are within the methods' scope.. The reading needs to be corrected to the reference temperature by means of Petroleum Measurement tables (ISO 91-1 [43]), when the density is measured at a temperature different from the reference temperature (i.e. Fifteen °C). However, these tables are not available for E10+ fuels and therefore need to be updated in cooperation with the originators, i.e. API and EI. Work is planned in API but the whole project of revision might take up to 3 years. Besides, it is necessary to verify the precision of the method for a full range of blends. The time needed to realise this step would be close to two months.

9.2.7 Oxidation stability

The oxidation stability test method, EN ISO 7536 [44] does not specifically mention fuels containing oxygenates. The applicability of this standard has been considered for E85 fuel [17] and found suitable. Therefore this test method was included in CEN/TS 15293 [45]. There's no need to check the applicability of the method for E10+ separately. The current test method equipment is believed to be suitable.

ASTM D7525 [46] covers the quantitative determination of the stability of spark ignition fuel, including those containing alcohols or other oxygenates, under accelerated oxidation conditions, by an automatic instrument (PetroOxy apparatus). This test method could also be used for E10+ fuels, but has not yet been correlated to the regular apparatus. Verification is first required.

9.2.8 Gum

EN ISO 6246 [47] specifies a method for the determination of the existent gum content of aviation fuels, and the gum content of motor petrols or other volatile distillates in their finished form, and at the time of test. The equivalent method, ASTM D381,[48] includes fuels up to E10 and no future work on E10+ is in hand or planned. A work programme would require a full study to cover a range of concentrations of oxygenates. The current test method equipment is considered to be suitable and a round robin would be needed to evaluate precision values for E10+-fuels. The round robin could take 1 year to 2 years to implement. No other issues are anticipated and it is expected that such work will be successful.

9.2.9 Copper strip corrosion

The copper strip corrosion test, EN ISO 2160 [49] does not specifically mention fuels containing oxygenates. ASTM is planning a study to cover up to E10.

Extending the scope to cover E10+ would require a limited robustness trial as the original test method does not have a precision statement. A typical robustness study would take 6 months - 12 months with further time required to update the test method. No issues are anticipated and would normally expect such a test programme to be successful. The current test method equipment is believed to be suitable.

9.2.10 Hydrocarbons (olefins and aromatics)

The hydrocarbon type content (e.g. olefins and aromatics) can be measured by EN ISO 22854 [51] or EN 15553 [50].

EN 15553 (Fluorescent Indicator Absorbance, FIA [50]): this test method analyses aromatic hydrocarbons in the range of 5 % (*V/V)* to 99 % (*V/V)* and olefinic hydrocarbons between 0,3 % (*V/V)* and 55 % (*V/V)* in oxygenate-free petrol. For oxygenated petrol the hydrocarbon type results can be reported on an oxygenate-free basis or, when the oxygenate content is known, the results can be corrected to a total-sample basis. The method may be less precise for E10+ fuels once the level of oxygenates becomes a major part of the fuel. On a total-sample basis the precision will be affected as it gets dependent on other methods to determine oxygenate content. Applicability and precision shall be tested in a Round Robin, which may take 1 year to 2 years to finalise.

EN ISO 22854 (Multidimensional GC [51]): this method covers the range of up to 50 % (*V/V)* aromatics and olefins between 1,5 % (*V/V)* and 30 % (*V/V)*. The method is applicable to samples containing higher percentages of oxygenates either by diluting the sample before being analysed or reducing the injection volume. In the diluted sample the dilutant is not integrated and the results are normalised to 100 %. Applicability needs to be confirmed for the hydrocarbon determination through a ruggedness study. Timeframe is estimated to be between 6 months to 12 months.

9.2.11 Oxygen and oxygenates

It is advisable for the oxygenate test methods to have an idea about the oxygenate composition of the sample in order to select the best conditions to analyse it, such as the required dilution step and operating parameters. This will get particular important once the amount of oxygen in petrol is increasing.

EN ISO 22854 (Multidimensional GC [51]): the current revision of this method will cover E10 samples with a maximum oxygen content of 3,7 % (*m/m*) and include a procedure for analysing oxygenates in high ethanol fuels (E85). Samples containing higher percentages of oxygenates should either be diluted before being analysed or the injection volume should be adequately reduced. Applicability for high ethanol fuels was tested in an E85 round robin, but should be confirmed through a ruggedness study. Timeframe is approx. Six months.

EN 13132 (GC with column switching [52]): this method analyses oxygenated compounds from 0,17 % (*V/V)* up to 15 % (*V/V)* and has a max oxygen content of 3,7 % (*m/m*) and should be revised for higher amounts of oxygenates. High amounts of ethanol may result in overlap of ethanol peak with other components such as methanol. High ethanol peaks may influence the retention time stability and valve switching times and it would therefore not be the preferred method. It should be considered removing it from the spec as the method requires detailed knowledge on the type of oxygenates present in the sample. Feasibility study required and applicability after revision needs confirmation through a round robin. Timeframe is approx.12 months.

EN 1601 (O-FID [53]): has the advantage that it is a dedicated method for determining oxygenates in light hydrocarbon streams and will identify most oxygenates commonly occurring in petrol. This method analyses oxygenated compounds from 0,17 % (*V/V)* up to 15 % (*V/V)*. For samples with higher oxygenates above 15 % (*V/V)* the sample should be diluted. The method is currently being updated to include samples up to

3,7 % (*m/m*) oxygen. Method applicability will need confirmation through a ruggedness study. Timeframe is approx. Six months.

NOTE The number of laboratories in Europe using either EN 13132 [52] or EN 1601 [53] is limited and continuously decreasing.

9.2.12 Benzene

EN ISO 22854 (Multidimensional GC [51]): when following the procedure described in the standard, samples containing higher percentages of ethanol should either be diluted before being analysed or the injection volume should be adequately reduced. The method is applicable up to 2 % (*V/V)* benzene. Applicability is already confirmed through a ruggedness study on E85 fuels.

EN 12177 (GC with column switching [54]) analyses benzene in the range of 0,05 % (*V/V)* to 6 % (*V/V)* benzene. Higher amounts of some oxygenates such as ethanol on the first column may influence the retention time stability and valve switching times. Feasibility test is needed and applicability needs confirmation through ruggedness study.

EN 238 (infrared spectrometry [55]) determines benzene in the range of 0,1 % (*V/V)* to 20 % (*V/V)*. The method would not need to be modified but applicability should be checked for any interference and confirmed in a ruggedness study. Timeframe is approx. Six months.

NOTE The number of laboratories using either EN 12177 or EN 238 for the current petrol specifications is limited and decreasing.

9.2.13 Vapour pressure

9.2.13.1 DVPE

EN 13016-1 [56] specifies a method for the determination of the total pressure, exerted *in vacuo*, by volatile, low viscosity petroleum products, components, and feedstocks containing air. A dry vapour pressure equivalent (DVPE) can be calculated from the air containing vapour pressure (ASVP) measurement. The conditions used in the test described in this standard are a vapour-to-liquid ratio of 4:1 and a test temperature of 37,8 °C.

Modern test apparatus for this test was first developed in 1987 and has significantly evolved. There are large number of instruments is use today throughout Europe for EN 228 fuel testing. Generally the precision is good and modern instrumentation is available from a number of manufacturers in Europe. The test method lists different precision for 1000 mL and 250 mL samples. It is desirable that these be consolidated for simplicity.

Oxygenates are not expected to cause any instrumental issues due to the seals and materials used.

ASTM trials performed on the equivalent ASTM D5191 [57] showed that precision (repeatability only) is OK up to E85. It was not proven if the equation used to give DVPE (Dry Reid vapour pressure equivalent) is still valid for E10+ fuels. The validity of the DVPE equation should not be seen as an issue.

9.2.13.2 Triple expansion method

This method is standardised in ASTM D6378.[58] This test method covers the use of automated vapour pressure instruments to determine the vapour pressure exerted in vacuum by volatile, liquid petroleum products, hydrocarbons, and hydrocarbon-oxygenate mixtures. This test method is suitable for testing samples with boiling points above 0 °C that exert a vapour pressure between 7 kPa and 150 kPa at 37,8 °C at a vapour-to-liquid ratio of 4:1.

This ASTM method removes the need to chill and air saturate the test sample, thus saving operator time. Precision is very similar to EN 13016-1 [56] and apparatus is available that can do both tests. Checks that the precision for E10+ is not changed have not been carried out but this is seen as low risk. The output of this test can be made to be DVPE by applying a 1 kPa bias correction. However, it is not known if this correction is valid for E10+ up to E85 and limited tests have shown some discrepancies.

Adoption of this test principle in a CEN test method would require a new test method and a precision exercise over a two year period before the new method was ready for EN 228. The acceptance of the test technique as such shall first be done by WG 21.

9.2.14 Distillation

EN ISO 3405 [59] specifies a laboratory test method, utilising either manual or automated equipment, for determining the distillation characteristics of light and middle distillates derived from petroleum and having initial boiling points above 0 °C and end points below approximately 400 °C. Light distillates are typically automotive engine petrols, automotive engine petrols with up to 10 % (*V/V*) ethanol and aviation petrols.

The applicability and the precision for E10+ fuels need to be fully assessed. The round robin and the successive revision of the Standard can take 3 years. The flatting of the boiling curve for E10+ fuels around the E70 distillation point can pose a precision issue.

9.2.15 Sampling

Generally, samples are taken as described in EN ISO 3170 [60] and EN ISO 3171 [61]. These standards are also applicable to E10+ fuels.

9.3 Potential new petrol fuel requirements

9.3.1 Sulfate

Sulfate salts dissolved in fuel can cause significant deposit formation inside pumps and injectors, e.g. at the orifice of the injection valve, resulting in non-compliance with the high-mileage emission requirements. Sulfate salts could also block petrol particulate filters. In general the limit on sulfate in the ethanol specification (EN 15376) can be considered strict enough. Therefore, this contaminant has not to be taken into account on E10+ specifications.

The test method presently provided for sulfate control in EN 15376 is EN 15492 [19] based on ion chromatography (IC). IC has been proven to be a reliable test method for determination of sulfate. The current method covers the range of sulfate from about 1 mg/kg to about 20 mg/kg in ethanol only. The method is not applicable to E10+ as is and will probably require significant modifications of the protocol.

9.3.2 Chlorides

The content of chlorides is covered by the ethanol specification (EN 15376). Therefore, this element has not to be taken into account on E10+ specifications. The current method to measure chloride content (EN 15492 [19]) is based on ionic chromatography (IC) and covers the range of chloride from about 1 mg/kg to about 30 mg/kg. The method is not applicable to E10+ as is and will probably require significant modifications of the protocol. As the quality of ethanol would be guaranteed by its specification, the risk of additional chloride content should be very low for E10+.

9.3.3 Iron

In the Fuels Quality Directive [4] manganese in fuels is limited (see 9.2.2). In line with this, CEN is discussing a test method for iron (Fe), coming from iron-based octane boosting additives, as that element presents problems to the vehicles as well.

Within the framework of the development of new motorisations (and the addition of post-treatment systems for some vehicles), it is necessary to first identify the real consequences of present metals in the fuel on the functioning of the vehicle. This subject is to be discussed by the working groups on petrol specification and elemental analysis.

9.3.4 Ash forming components

Due to possible introduction of Petrol Particulate Filter in the future and higher cell density catalysts, the need for low ash content of an E10+ fuel should be taken into account. Ashes originate only from inorganic compounds. Based on previous work made on diesels, it would be good to be able to check trace elements amounts instead of limiting the ash content.

In the specific case of E10+, a list of 5 to 6 elements for immediate consideration should be defined and the applicability of ICP-AES method on E10+ could be evaluated. The time needed to realise those tests would be close to five months. By cooperation with ASTM D02, which is studying this topic, this period might be shortened.

9.3.5 Silver strip corrosion

In 2005 and 2006, CEN/TC 19/WG 21 (documents N114 and N123) recommended to check EN 228 fuel for silver corrosion at every batch and in particular after refinery check-ups. Current silver corrosion test methods are ASTM D7671 [62] ASTM D7667 [63] and IP 227 [64]. The continuation of this recommendation for E10+ fuels is subject for discussion by WG 21.

9.3.6 High boiling components

EN 16270 [21] for analysing the high boiling fraction including FAME in EN 228 petrol is applicable to petrol containing different levels of ethanol. The method’s applicability is mainly limited by its measurement range. It will therefore be required to run a round robin on fuels containing larger amounts of low boiling components such as alcohols and ethers, to determine the precision and measurement range.

There is currently a preliminary work item to determine high boiling material in E85. Once this method is activated it will give a better understanding about the system’s precision and measurement range for such samples and another round robin may not be required.

9.4 Summary

The assessment of test methods for fuel specifications is summarised in Table 4. Apart from the current scope and status of availability, it shows the time required for test method verification and evaluation and that for the revision of the test methodology and standard.

Existing industry procedures for evaluating hot and cold weather driveability performance, as described in 7.5 and 7.8, should also be updated to evaluate modern vehicles, especially those with active EMS, ABS, and ‘drive by wire’ technologies. Updated procedures are needed to reliably evaluate the performance of modern vehicles on both today’s and tomorrow’s fuels and complement the in-house approaches that are already used by vehicle manufacturers and their suppliers for new vehicle developments.

Table 4 — Assessment of the applicability of test methods for E10+ fuels

Parameter	**Current scope**	**Current status of applicability**	**Verification / evaluation** (months)	**Revision** (years)	**Comments**
Sulfur					
EN ISO 20846	E10, (3 – 500) mg/kg	Check only	1	2 - 3	1st option
EN ISO 20884	E10, (5 – 500) mg/kg	Check only	2	2 - 3	Matrix dependent
ICP-AES	-	Unknown	6 - 12	3	Not in current EN 228
Manganese					
EN 16135	E5 to E 10, (2 – 8) mg/l	Check only	5	1 - 2	AAS
EN 16136	E5 to E10, (2 – 8) mg/l	Check only	5	1 - 2	ICP: 1st option (availability)
Lead	E10, (2,5 – 10,0) mg/l	Check only	1	1 - 3	
RON/MON	E10, 40 – 103	Applicable but to be checked	-	2 - 3	Experimental work done by ASTM, but to be checked
Density	E10, (600 – 1 100) kg/m3	Applicable	-	3	Petroleum measurement tables need to be updated
Oxidation stability					
EN ISO 7536	E10, E85	Applicable	12 - 24	2 - 3	
ASTM D7525	E10	Full assessment	12 - 24	2 - 3	Not in current EN 228
Existent gum	E10, E85, 0 – 30 mg/100 ml	Full assessment	12 - 24	2 - 3	
Copper strip corrosion	E10, E85	Check only	6 - 12	1 - 3	
Hydrocarbons					
EN 15553	Olefins: 0,3 – 55 %(*V/V*)	Full assessment	12 - 24	2 - 4	
EN ISO 22854 [a]	Aromatics: 5 – 99 %(*V/V*) Olefins: 1,5 – 30 %(*V/V*) Aromatics: < 50 % (*V/V*)	Check only	6 - 12	1 - 2	1st option (availability)
Oxygenates					
EN ISO 22854 [a]	(0,8 – 15) % (*V/V*)	Check only	6	1 - 3	1st option (availability)
EN 13132 [a]	(0,17 – 15) % (*V/V*)	Full assessment	12	2 - 3	3rd option
EN 1601	(0,17 – 15) % (*V/V*)	Check only	6	1 – 2	2nd option (limited laboratories)

Parameter	Current scope	Current status of applicability	Verification / evaluation (months)	Revision (years)	Comments
Benzene					
EN ISO 22854 [a]	< 2 % (*V/V*)	Applicable	6	1 - 2	1st option, confirmed for 85
EN 12177 [a]	(0,05 – 6) % (*V/V*)	Check only	6	1 - 2	2nd option
EN 238	(0,1 – 20) % (V/V)	Check only			3rd option
Vapour pressure					
EN 13016–1	E10, E85,	Check only	2	1 - 2	Check DVPE equation ?
ASTM D6378	(9,0 - 150,0) kPa	Full assessment	12	2 - 3	Not in current EN 228
Distillation	E10	Full assessment	12	2 - 4	
Sampling		Applicable	-		
EN ISO 3170	E10			-	
EN ISO 3171	E10				

[a] The time required for method revision does not take into account the potential increasing variability of the blend stocks

10 Conclusions

The European Union is following a policy of promoting renewable energy use in Europe and could encourage the future introduction of petrol having higher fractions of oxygenates derived from renewable sources, such as ethanol and other oxygenates. Anticipating the potential introduction of E10+ petrol in the future, CEN/TC 19 has drafted this overview and time plan for necessary test methods and requirements which are expected to form the basis for future work items related to petrol.

Assuming that European legislation ([2],[3] and[4]) is amended with the legal parameters for an E10+ petrol, a nominal specification for E10+ petrol, based on sound technical data, will take several years to develop and thoroughly evaluate in laboratory and vehicle tests. A first draft of a new fuel specification could be developed fairly quickly within CEN/TC 19 once the legal parameters are known. A detailed overview is given in Figure 15, but at least two years of evaluating these test methods is anticipated in order to demonstrate their compatibility with E10+ petrol. Test procedures for evaluating the driveability performance of newer vehicle technologies should also be updated to enable the evaluation of both current and future petrol blends.

In parallel checks on refinery and logistical chain matters should be done. It would then take about 2 years more to develop a new draft petrol fuel specification and revising the ethanol blend component specification (EN 15376) where necessary. This would also require updating the test method standards and assessing ethanol production capabilities on the basis of the newly developed test methods.

After all the CEN/TC 19 standards are essentially in place, meaning having passed the enquiry phase, the car manufacturers and fuel suppliers would need to agree on a test fuel that will be used for a one year or more assessment period in order to check motor management (calibration), engine compatibility and emissions impact. Fuel producibility and supply logistics would also be evaluated during this time. Following this work, some additional years would be required to develop and commercialise E10+ capable vehicles, followed by up to five years to commercialise E10+ optimised vehicles. Therefore, the path to successful implementation of an E10+ petrol grade will be complicated, requiring considerable research on vehicles and test methods and coordination amongst all industry stakeholders and an estimated time path of about 10 years to 11 years.

A feasible E10+ introduction scenario after political decision may be practicable as in Figure 15, involving following important steps:

a) E10+ standardization mandate from EC to CEN is the trigger. Before mandate is issued, the introduction scenario and the target blend level needs to be agreed upon amongst all stakeholders;

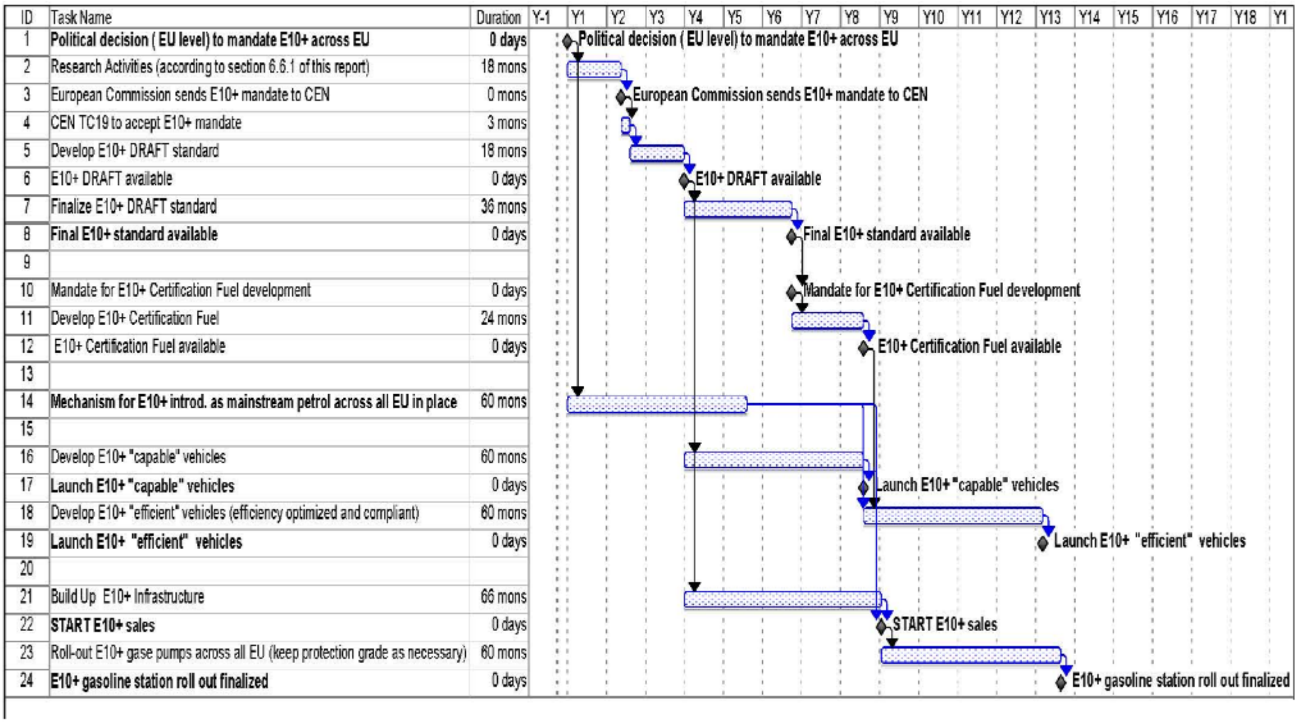
b) development of a reliable draft E10+ quality specification standard (supported by the necessary bio-blend component specifications), before the oil industry can start to prepare the fuel distribution infrastructure to E10+ and the automotive industry can start developing E10+ "capable" vehicles;

c) finalisation of E10+ standard and preparation of E10+ fuel distribution infrastructure as well as development of E10+ "capable" vehicles in parallel;

d) once specific mechanisms for E10+-fuel introduction as a mainstream fuel have been introduced, E10+ "capable" vehicles need to be introduced first in order get some potential consumers on the road, before the fuels distribution infrastructure is going to be developed;

e) once E10+ distribution infrastructure is almost fully established E10+ "optimised" (CO_2 reducing) vehicles can be launched.

EC funding may also be needed at an early stage to complement on-going stakeholder research and answer many of the technical questions that are related to E10+ petrol specifications and test methods (see, for example, 6.6.1).



ID	Task Name	Duration
1	**Political decision (EU level) to mandate E10+ across EU**	0 days
2	Research Activities (according to section 6.6.1 of this report)	18 mons
3	European Commission sends E10+ mandate to CEN	0 mons
4	CEN TC19 to accept E10+ mandate	3 mons
5	Develop E10+ DRAFT standard	18 mons
6	E10+ DRAFT available	0 days
7	Finalize E10+ DRAFT standard	36 mons
8	**Final E10+ standard available**	0 days
9		
10	Mandate for E10+ Certification Fuel development	0 days
11	Develop E10+ Certification Fuel	24 mons
12	E10+ Certification Fuel available	0 days
13		
14	**Mechanism for E10+ introd. as mainstream petrol across all EU in place**	60 mons
15		
16	Develop E10+ "capable" vehicles	60 mons
17	**Launch E10+ "capable" vehicles**	0 days
18	Develop E10+ "efficient" vehicles (efficiency optimized and compliant)	60 mons
19	**Launch E10+ "efficient" vehicles**	0 days
20		
21	Build Up E10+ Infrastructure	66 mons
22	**START E10+ sales**	0 days
23	Roll-out E10+ gase pumps across all EU (keep protection grade as necessary)	60 mons
24	**E10+ gasoline station roll out finalized**	0 days

Figure 15 — Estimated minimal time path for E10+ introduction

11 Acknowledgement

The kind contributions of all the CEN/TC 19/WG 38 experts are warmly acknowledged.

Annex A
(informative)

Abbreviations

The following abbreviations are used in the document

Abbreviations	Meaning
ABS	Antilock Braking Systems
ACEA	Association des Constructeurs Européens d'Automobiles (European Automobile Manufacturers' Association)
AENOR	Spanish Association for Standardization and Certification
AFNOR	Association Française de Normalisation (French Standards Institute)
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ASVP	Air Saturated Vapour Pressure
ATDC	After Top Dead Center
BLD	Borderline Detonation
BMEP	Braek Mean Effective Pressure
BOB	Blendstock for Oxygenate Blending
BSI	British Standards Institute
BTDC	Before Top Dead Center
BTL	Biomass To Liquid
Ca	Calcium (element)
CA	Crank Angle
CARB	California Air Resources Board
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CENELEC	Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)
CFR	Cylinder Firing Rate or Cooperative Fuels Research (engine)
CO	Carbon monoxide
CO_2	Carbon dioxide
CONCAWE	CONservation of Clean Air and Water in Europe
CR	Compression Ratio
CRC	Coordinating Research Council
DI	Driveability Index
DIN	Deutsches Institut für Normung (German Standards Institute)
DME	Di-Methyl Ether
DVPE	Dry Vapour Pressure Equivalent

EC	European Commission
EFTF	Ethanol Fuel Task Force (under CEN/TC 19/WG 21)
EMS	Engine Management System
EN	European Norm
e-PURE	European renewable ethanol industry
ETBE	Ethyl Tertiary Butyl Ether
EU	European Union
FAME	Fatty Acid Methyl Ester
Fe	Iron (element)
FIA	Fluorescent Indicator Absorbance
FQD	Fuels Quality Directive
FVV	Forschungsvereinigung Verbrennungskraftmaschinen e.V. (Research Association for Combustion Engines)
GC	Gas Chromatography
GDI	Gasoline Direct Injection
GHG	Greenhouse gas
GPF	Gasoline Particulate Filters
GRP	Glass Reinforced Plastic
HC	Hydrocarbon
HVO	Hydrotreated (or Hydrogenated) Vegetable Oil (oranimal fat)
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
ICS	International Classification for Standards
IFC	Internal Ffloating Cover
ILS	Inter-Laboratory Study
IP	Institute of Petroleum, UK (now the Energy Institute)
IR	Infrared
ISO	International Organization for Standardisation
K	Potassium (element)
LEV	Low Emission Vehicles
Mg	Magnesium (element)
Mn	Manganese (element
MOGAS	Motor Gasoline
MON	Motor Octane Number
MTBE	Methyl Tertiary Butyl Ether
Na	Sodium (element)
NBN	Belgian Standards Institute
NEDC	New European Driving Cycle
NEN	Netherlands Standardization Institute

NOx	Nitrogen oxides
OBD	On-Board Diagnostics
O-FID	Oxygen Flame Ionisation Detector
ON	Octane Number
P	Phosphorus (element)
P/V	Pressure/Vacuum
PRF	Primary Reference Fuels
PVC	Polyvinyl Chloride
RED	Renewable Energy Directive,, 2009/28/EC
RFG	ReFormulated Gasoline
RON	Research Octane Number
RUFIT	Rational Use of Fuels in Private Transport
SCC	Stress Corrosion Cracking
SDS	Safety Data Sheet
SFS	Finnish Standards Institute
Si	Silicon (element)
SIS	Swedish Standards Institute
TC	Technical Committee
TC 19	CEN Technical Committee for Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin
TEL	Tetra Ethyl Lead
TF	Task Force
THC	Total HydroCarbon
TLEV	Transitional Low-Emission Vehicles
TR	Technical Report
TTW	Tank To Wheels
UNI	Ente Nationale Italiano di Unificazione (Italian standardization body)
UPEI	Union Pétrolière Européenne Indépendante (Independent European Petroleum Union)
UVF	Ultraviolet Fluorescence
VP	Vapour Pressure
WDXRF	Wavelength-Dispersive X-Ray Fluorescence
WG	Working Group
WLTP	Worldwide Harmonised Light-duty Vehicle Test Procedure
WTT	Well To Tank
WTW	Well To Wheels
Zn	Zinc (element)

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