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Fuel Quality

Proposal for a guideline on market fuel quality to be added to the Consolidated Resolution on the Construction of Vehicles

Submitted by the expert from the International Organization of Motor Vehicle Manufacturers *

The text reproduced below was prepared by the expert from the International Organization of Motor Vehicle Manufacturers (OICA) to propose a guideline on market fuel quality to be added to the Consolidated Resolution on the Construction of Vehicles (R.E.3). This document is based on Informal document No. GRPE-61-11-Rev.1 distributed at the sixty-first session of the Working Party on Pollution and Energy (GRPE) (ECE/TRANS/WP.29/GRPE/61, para. 44).

* In accordance with the programme of work of the Inland Transport Committee for 2010–2014 (ECE/TRANS/208, para. 106 and ECE/TRANS/2010/8, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

I. Proposal

Insert a new Annex 4, to read:

"Annex 4

Market fuel quality guideline

Note: This chapter contains recommendations for minimum market fuel quality linked to the level of emission requirements.

1. Purpose of the recommendation

This recommendation is intended to inform governments about appropriate market fuels for achieving desired vehicle emission requirements and to promote harmonization of market fuel quality to facilitate use of the necessary emission control technologies. This recommendation is mainly addressed to countries which are contemplating the introduction of new vehicle emission levels, in order to inform them about the necessary link between emissions requirements and the fuel quality on their markets.

2. Scope of the recommendation

This recommendation applies to fuel quality parameters directly affecting emissions control equipment performance and durability. However, there are also fuel quality parameters influencing the tailpipe emissions of a vehicle without having this direct influence on emissions control equipment.

3. Definitions and abbreviations

[As necessary]

4. Introduction

4.1. The World Forum WP.29 has acknowledged that market fuel quality is closely linked to the emissions of pollutants from motor vehicles. On the other hand regulations and specifications of market fuel quality are not yet well harmonized and they are not always fully aligned with the vehicle technology necessary to meet stipulated emissions regulations. More stringent emission regulations require more advanced emission control technologies, which drive the crucial need for improved market fuel quality.

4.2. This recommendation defines a list of key fuel parameters linked to legally required emissions levels and suggests the minimum fuel quality requirements corresponding to vehicle technologies needed to achieve the concerned emission levels. It has to be recognized that, as mentioned in the scope, other parameters can influence the tailpipe emissions of vehicles and thus adherence to this limited list may not be sufficient to enable durable compliance to the relevant emissions standards for all vehicle concepts.

4.3. The list of parameters has been herewith linked to the so-called Euro 2, 3, 4 emission levels. An extension to more stringent levels will be needed in due time to keep the recommendation updated with the technical progress.

5. Fuel quality recommendations

5.1. Gasoline quality

Gasoline parameters[1]	*Euro 2 emissions enabling fuel*[2]	*Euro 3 emissions enabling fuel*[3]	*Euro 4 emissions enabling fuel*[4]	*Test method*
Sulphur (mg/kg or ppm)	≤ 500	≤ 150	≤ 50[5]	EN ISO 20846 EN ISO 20884
Lead[6] (g/l)	no intentional addition, with max ≤ 0.013	no intentional addition, with max ≤ 0.005	no intentional addition, with max ≤ 0.005	EN 237
Manganese[7] (mg/l)	no intentional addition	no intentional addition	no intentional addition	ICP or ASTM D 7111
Iron[8] (mg/l)	no intentional addition	no intentional addition	no intentional addition	ICP or ASTM D 7111
Phosphorus (mg/l)	no intentional addition	no intentional addition	no intentional addition	EN 14107
Oxygen content[9] (% m/m)				EN 1601 EN 13132
Oxygenates (% v/v) - methanol - ethanol[10]				EN 1601 EN 13132
RVP (kPa)				EN 13016/l DVPE
RON (-)[11]				EN ISO 5164
MON (-)[12]				EN ISO 5163

[1] See Annex 1 and Annex 3.

[2] See Regulation No. 83.03.

[3] See Regulation No. 83.05 (row A).

[4] See Regulation No. 83.05 (row B).

[5] Clarify the footnote: The United Nations Environment Programme (UNEP) decision taken at the fourth global meeting of the Partnership for Clean Fuels and Vehicles (PCFV), held on 14 and 15 December 2005 in Nairobi, Kenya. See Annex 1, Sulphur.

[6] Potassium-containing additives may be used in Lead Replacement Petrol (LRP). See Annex 1, Lead.

[7] The European Commission (EC) has established limit values for manganese content to be implemented from 1 January 2011, and is assessing the impact of manganese on health and the environment as mandated by the EU Fuel Quality Directive (2009/30/EC). The manganese content in gasoline is also limited in China (GB 17930-2006) and in Beijing (DB 11/238-2007). See Annex 1, Manganese.

[8] The iron content in gasoline is currently limited in Vietnam (TCVN 6776:2005) and in China (GB 17930-2006). See Annex 1 Paragraph, Iron.

[9] The oxygen content and the vehicle technology shall be fully compatible in order to ensure satisfactory vehicle performance and compliance with emissions standards. See Annex 1, Oxygen.

[10] The ethanol content and the vehicle technology shall be fully compatible in order to ensure satisfactory vehicle performance and compliance with emissions standards. Many engine and vehicle manufacturers have established acceptable operating limits for ethanol concentrations and specifications. For more information, see the vehicle owner's manuals and ethanol specifications that apply in the European Union (EN 15376) and United States of America (ASTM D 4806). See Annex 1, Oxygen and Oxygenates.

[11] Add footnote on the relevance of RON to emissions performance. See Annex 1, RON.

[12] Add footnote on the relevance of MON to emissions performance. See Annex 1, MON.

5.2. Diesel fuel quality

Diesel fuel parameters[13]	*Euro 2 emissions enabling fuel*[14]	*Euro 3 emissions enabling fuel*[15]	*Euro 4 emissions enabling fuel*[16]	*Test method*
Sulphur (mg/kg)	≤ 500	≤ 350	≤ 50[17]	EN ISO 20846 EN ISO 20884
Ash (% m/m)	≤ 0.01	≤ 0.01	≤ 0.01	EN/ISO 6245
Total Contamination (mg/kg)	≤ 24	≤ 24	≤ 24	EN 12662
Water (mg/kg)				EN ISO 12937
Cetane Number[18]				EN ISO 5165
Cetane Index[19]				EN ISO 4264
Density (kg/m3) at 15°C				EN ISO 3675 EN ISO 12185
Viscosity[20] (mm2/s)				EN ISO 3104
Flash Point (°C)				EN ISO 2719
FAME[21] (% v/v)				EN 14078
Lubricity[22] (microns)				ISO 12156-1

6. References

[if necessary]

[13] See Annex 2 and 3.
[14] See Regulation No. 83.03 and R. 49.02 (Stage II).
[15] See Regulation No. 83.05 (row A) and Regulation No. 49.03 (row A).
[16] See Regulation No. 83.05 (row B) and Regulation No. 49.03 (row B1).
[17] Clarify this footnote as per the corresponding gasoline footnote: UNEP decision taken at the 4th global PCFV meeting, 14 and 15 December 2005 in Nairobi, Kenya. See Annex 2, Sulphur.
[18] Add footnote on relevance of Cetane number and country limits. See Annex 2, Cetane number.
[19] Add footnote on relevance of Cetane index and country limits. See Annex 2, Cetane index.
[20] Add footnote to reference CEN/ASTM limits (for example) See Annex 2, Viscosity.
[21] The Fatty Acid Methyl Ester (FAME) concentration and specifications shall be fully compatible with the vehicle technology to ensure satisfactory vehicle performance and compliance with emissions standards. Many engine and vehicle manufacturers have established acceptable operating limits for FAME concentrations and specifications. For example, see vehicle owner's manuals and FAME specifications that apply in the European Union (EN 14214) and United States of America (ASTM D 6751). NOTE: Add prevailing country limits as was done in the ethanol section (Explanatory Annex 1). See Annex 2, FAME.
[22] Diesel fuel lubricity usually improves with higher fuel sulfur concentrations. Acceptable fuel lubricity should be ensured because it is an important property for maintaining the long-term performance of fuel injection equipment. See Annex 2, Lubricity.

Appendix 1

Gasoline properties

1. Sulphur

1.1. Sulphur occurs naturally in crude oil. Sulphur has a significant impact on vehicle emissions as it reduces the efficiency of catalysts. Sulphur also adversely affects heated exhaust gas oxygen sensors. Reductions in sulphur will provide immediate reductions of emissions from all catalyst-equipped vehicles on the road.

1.2. Extensive testing has been done on the impact of sulphur on vehicle emissions. Studies such as those performed by Air Quality Improvement Research Program (AQIRP) in the United States of America, Auto-Oil programme in Europe and Japan Clean Air Programme (JCAP) in Japan have shown that significant emission reductions with different vehicle technologies as sulphur is reduced.

1.3. Stringent emission regulations, combined with long-life compliance requirements, demand extremely efficient and durable exhaust after-treatment systems. Furthermore, fuel sulphur will also negatively affect the feasibility of advanced on-board diagnostic systems.

2. Lead (Tetra Ethyl Lead (TEL))

2.1. Lead alkyl additives have been used historically as inexpensive octane enhancers for gasoline. Concerns over health effects associated with the use of these additives, and the need for unleaded gasoline to support vehicle emission control technologies such as catalytic converters and oxygen sensors, have resulted in the elimination of leaded gasoline from many markets. As vehicle catalyst efficiencies have improved, tolerance to lead contamination is very low, so that even slight lead contamination can poison a catalyst. As catalyst-equipped vehicles are introduced into developing areas, unleaded gasoline shall be available. Removal of lead compounds from gasoline reduces vehicle hydrocarbon emissions, even from vehicles without catalytic converters. A lead-free market worldwide is therefore essential, not only for emission control compatibility, but also because of the well-known adverse health effects of lead.

3. Manganese (Methylcyclopentadienyl Manganese Tricarbonyl (MMT))

3.1. MMT is a manganese-based compound marketed as an octane-enhancing fuel additive for gasoline. Studies have shown that only a small percentage of the MMT-derived manganese from the fuel is emitted from the tailpipe — the majority remains within the engine, catalyst and exhaust system.

(a) The combustion products of MMT coat internal engine components such as spark plugs, potentially causing misfire which leads to increased emissions, increased fuel consumption and poor engine performance. These conditions result in increased owner dissatisfaction and expenses for consumers and vehicle manufacturers.

(b) The combustion products of MMT also accumulate on the catalyst. In some cases, the front face of the catalyst can become plugged with deposits, causing poor vehicle operation and increased fuel consumption in addition to reduced emission control.

3.2. Given this body of information, there are strong concerns with MMT's impact on the highly sensitive technologies that are required to meet present and future emissions regulations.

3.3. While the use of MMT is already restricted in several world markets, vehicle manufacturers experience the adverse effects of this additive in countries where it is still being used.

4. Iron (Ferrocene)

4.1. Ferrocene has been used to replace lead as an octane enhancer for unleaded fuels in some markets. It contains iron, which deposits on spark plugs, catalysts and other exhaust system parts as iron oxide, and may also affect other engine components. The deposits will cause premature failure of the spark plugs, with plug life being reduced by up to 90 per cent compared to normal service expectations. Failing spark plugs will short-circuit and cause misfiring when hot, such as under high load condition. This may cause thermal damage to the exhaust catalyst.

4.2. Iron oxide also acts as a physical barrier between the catalyst/oxygen sensor and the exhaust gases, and also leads to erosion and plugging of the catalyst. As a result the emission control system is not able to function as designed, causing emissions to increase. Additionally, premature wear of critical engine components such as the pistons and rings can occur due to the presence of iron oxide in the vehicle lubrication system.

5. Phosphorus

5.1. Phosphorous negatively affects catalyst performance by blocking the catalytic sites.

6. Potassium, Sodium

6.1. Metal-containing additives are accepted for valve seat protection in non-catalyst cars only. In this case, potassium-based additives are recommended. In gasoline intended for catalyst equipped cars it is strongly recommended not to add potassium or sodium containing additives

7. Oxygenates

7.1. Oxygenated organic compounds, such as Methyl Tertiary Butyl Ether (MTBE), Ethyl Tertiary Butyl Ether (ETBE) and ethanol, are often added to gasoline. Oxygenates will increase octane, lower the CO and HC emission (particularly from unregulated cars) and, in the case of ETBE and ethanol, introduce biocomponents to the gasoline blend. Oxygenates have a lower heating value than the normal hydrocarbon components and this will induce a lean shift in the engine stoichiometric. Cars with closed-loop exhaust after treatment systems can, within certain limits, compensate for this stoichiometric shift but if the oxygenate levels are too high this is not possible anymore. Therefore, it is very important that the oxygen content of gasoline is controlled through well defined limits. Essentially all cars in the world can handle up to a maximum of 2.7 per cent oxygen and most of the newer technology cars (Euro 3 and 4) cars can work properly with up to a maximum of 3.7 per cent oxygen in the gasoline. For ethanol there are some specific issues that have to be taken into account. Ethanol increases the corrosiveness against certain materials and, when splash blended, increases the vapour pressure of the gasoline blend. If the vapour pressure is too high in relation to the operational and climatic conditions, there is a risk of vapour locks, creating operational disturbances of the cars, and also the risk of overfilling the carbon canister with evaporated hydrocarbons and ethanol. Most of the cars in circulation today can accept up to 5 per cent ethanol, newer technology cars (Euro 3 and 4) can in most cases accommodate up to 10 per cent ethanol. It is also very important to note that the ethanol component has to be free from impurities and have well controlled acidity.

8. Vapour pressure (Reid vapour pressure (RVP), Dry Vapour Pressure Equivalent (DVPE))

8.1. Proper volatility of gasoline is critical to the operation of spark ignition engines with respect to both performance and emissions. The vapour pressure of gasoline should be controlled seasonally to allow for the differing volatility needs of vehicles at different temperatures. 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.

8.2. Excessively high gasoline volatility can cause hot fuel handling problems such as vapour lock, canister overloading, and higher emissions. Vapour lock occurs when too much vapour forms in the fuel system and fuel flow decreases to the engine. This can result in loss of power, rough engine operation or engine stalls. Vapour pressure requirements for market gasoline should be set strictly in accordance with climatic and seasonal demands.

9. Octane (RON, MON)

9.1. Octane is a measure of a gasoline's ability to resist auto-ignition (knock). There are two test methods to measure gasoline octane numbers: one determines the Research Octane Number (RON) and the other the Motor Octane Number (MON). RON correlates best with low speed, mild-knocking conditions and MON correlates with high-temperature knocking conditions and with part-throttle operation. RON values are typically higher than MON and RON is the octane number quoted on the gasoline pumps at service stations in most countries.

9.2. Vehicles are designed and calibrated for a certain octane values, to cover all possible driving conditions. When a vehicle driver uses gasoline with an octane level lower than that required, knocking may result which could lead to severe engine damage. Engines equipped with knock sensors can handle lower octane levels by retarding the spark timing; however, fuel consumption, driveability and power will suffer and at low octane levels, knock may still occur. Using gasoline with an octane rating higher than that recommended will, in most cases, not improve the vehicle's performance. Gasoline with adequate octane ratings, covering the requirements of the whole vehicle fleet (see vehicle handbooks), should be available in all world markets.

Appendix 2

Property of diesel

1. Sulphur

1.1. Sulphur naturally occurs in crude oil. Sulphur in diesel fuel can have a significant effect on emission system performance and durability, as well as on engine life. As sulphur levels increase, relative engine life decreases as a result of increased corrosion and wear of the engine's components.

1.2. The efficiency of exhaust emissions control systems is generally reduced by sulphur and some emissions control technologies can be permanently damaged through blockage by sulphates. The impact of sulphur on particulate emissions is well understood and known to be significant. The fuel sulphur is oxidised during combustion to form SO_2, which is the primary sulphur compound emitted from the engine. Some of the SO_2 further oxidized to sulphates (SO_4). The sulphates and associated water coalesces around the carbon core of the particulates, which increases the mass of the particulate matter (PM). Thus fuel sulphur has a significant influence on the measured PM emissions.

1.3. For non-catalyst vehicles, the conversion of SO_2 into sulphates is quite limited, however, if an oxidative after-treatment system is applied, the conversion rate to sulphates is dramatically increased. This can drastically increase the amount of PM emitted from the vehicle and has a significant impact on the efficiency and durability of the vehicle after-treatment system.

1.4. Diesel Particulate Filters (DPF) allow vehicles to achieve extreme particulate emissions levels and DPFs are widely applied to meet stringent emissions requirements. Particularly in oxidative DPF systems, the fuel sulphur will constitute a significant technical risk. The non-regenerable sulphates will gradually block the filter, causing the back-pressure over the filter to rise, and thus negatively affect the performance of the engine and the durability of the filter itself.

2. Ash

2.1. Fuel and lubricant derived ash can contribute to coking on injector nozzles and will have a significant effect on the life of diesel particulate filters. Ash-forming metals can be present in fuel additives, lubricant additives or as a by-product of the refining process.

2.2. Metallic ash constituents are incombustible, so when they are present in the fuel, they remain in the exhaust and become trapped within the DPF. Thus, the presence of ash-forming materials in the fuel will lead to a premature build-up of backpressure and vehicle operability problems. Non-fuel solutions have been found unsatisfactory. Larger filters would reduce backpressure build-up but otherwise would be unnecessary and may be infeasible (for example, in smaller vehicles). Increased in-use maintenance or, in extreme cases, replacing the DPF may not be allowed in some markets.

3. Total contamination

3.1. Fuel injection equipment manufacturers continue to develop fuel injection systems to reduce emissions and fuel consumption and to improve performance. Injection pressures have been increasing; currently, they have passed 200 MPa (2,000 bars) and even higher levels are expected in the future. Such levels of injection pressure demand reduced orifice sizes and component clearances. Small hard inorganic particles, which may be carried into these engine parts, are potential sources of excessive wear, leading to premature component failures. Excessive diesel fuel contamination (both from inorganic and organic particles/sediments) can also cause premature clogging of the fuel filters, leading to operational disturbances and higher service costs.

4. Water

4.1. Strict water control in each step of the fuel distribution system, including the vehicle tank, is essential for good engine component durability (corrosion) and vehicle performance.

5. Cetane, number and index

5.1. Cetane number is a measure of the compression ignition behaviour (ignition delay) of a diesel fuel. Cetane number influences particularly cold start-ability, exhaust emissions and combustion noise. The cetane number is measured in a single cylinder test engine

5.2. Cetane index, which is based on measured fuel properties (density and distillation points), is a calculated value that approximates the 'natural' cetane of a fuel ("natural" cetane is the cetane number when the fuel does not contain cetane improver).

5.3. A higher cetane number will decrease engine cranking time at cold start, which in turn will affect the exhaust emissions positively (lower hydrocarbons). Several industry test programmes, for instance the European Union Auto-Oil, have confirmed that higher cetane numbers will improve also the NOx emissions, particularly in heavy duty engines.

6. Density and viscosity

6.1. The diesel fuel injection is controlled volumetrically or by timing of the solenoid valve. Variations in fuel density and viscosity result in variations in engine power output and, consequently, in engine emissions and fuel consumption.

6.2. Diesel engines are calibrated (for emissions, performance, driveability) on reference fuels with quite narrow parameter spans. This is also the case for density and viscosity.

6.3. If density/viscosity is significantly higher than the reference fuel: the emissions (smoke, PM) will increase and the engine can come be "overpowered", leading to durability problems with engine components.

6.4. If density/viscosity is significantly lower than the reference fuel: lower power output than rated power, which leads to poor driveability, decreased customer satisfaction and higher fuel consumption.

7. FAME

7.1. Fatty Acid Methyl Esters (FAME), frequently termed biodiesel, increasingly are being used to extend or replace fossil diesel fuel. The use of biodiesel is driven largely by efforts to reduce dependency on petroleum-based products, to enhance use of agricultural products as fuels and to facilitate Greenhouse Gas (CO_2) reduction ambitions for the transport sector.

7.2. Several different vegetable oils are used to make biodiesel, for example oils from rapeseed, sunflower, palm and soy. These oils are reacted with an alcohol (methanol in the case of FAME) to form ester compounds before they can be used as biodiesel fuel.

7.3. Unprocessed vegetable oils, animal fats and other non-esterified fatty acids are not acceptable fuels for on-road diesel engines due to their low cetane number, inappropriate cold flow properties, high injector fouling tendency and high kinematics viscosities. The European Standards Organisation (CEN) has issued a standard (EN 14214) that establishes specifications for FAME as blendstock for conventional diesel fuel. A similar standard has been issued by ASTM (ASTM D 6751)

7.4. Generally, biodiesel enhances the lubricity of conventional diesel fuel and reduces exhaust gas particulate matter. Also, the production and use of biodiesel fuel is reported to lower carbon dioxide emissions on a source to wheel basis, compared to conventional diesel fuel.

7.5. There are, however, some technical issues that should be considered when blending biodiesel (FAME) into diesel fuel:

7.6. Biodiesel may be less stable than conventional diesel fuel, precautions are needed to avoid problems linked to the presence of degradation products in the fuel. Some fuel injection equipment data suggests that such problems may be exacerbated when biodiesel is blended with ultra-low sulphur diesel fuels.

7.7. Particularly if used at higher blend levels, biodiesel needs special care at low temperatures to avoid an excessive rise in viscosity and loss of fluidity.

7.8. Being hygroscopic, biodiesel fuels require special handling to prevent high water content and the consequent risk of corrosion and microbial growth.

7.9. Deposit formation in the fuel injection system may be higher with biodiesel blends than with conventional diesel fuel, it is therefore advised that detergent additives are used.

7.10. Biodiesel may negatively impact natural and nitrile rubber seals in fuel systems. Also, metals such as brass, bronze, copper, lead and zinc may oxidize from contact with biodiesel, thereby creating sediments. A transition from conventional diesel fuel to biodiesel blends may significantly increase tank sediments due to biodiesel's higher polarity, and these sediments may plug fuel filters. Thus, fuel system parts shall be specially chosen for their compatibility with biodiesel.

7.11. A useful handling guideline for FAME and FAME blends has been published by the European Oil Companies Organisation for Environment, Health and Safety (CONCAWE) (www.unece.org/trans/doc/2011/wp29grpe/ECE-TRANS-WP29-GRPE-61-inf27e.pdf).

8. Lubricity

8.1. The lubricating components of the diesel fuel are understood to be the heavier hydrocarbons and polar fuel compounds. Diesel fuel pumps, without an external lubrication system, rely on the lubricating properties of diesel fuel to ensure proper operation.

8.2. Refining processes to remove sulphur tend to simultaneously reduce diesel fuel components that provide natural lubricity. As diesel fuel sulphur levels decrease, the risk of inadequate lubricity also increases; however, poor lubricity has been observed even in diesel fuels with very high sulphur levels. Inexpensive additives can be used instead of changing the refining process to achieve the desired lubricity level.

8.3. Inadequate lubricity can result in increased tailpipe emissions, excessive pump wear and, in some cases, catastrophic failure. Concerns over problems experienced with fuels with poor lubricity led to a significant international collaboration between oil companies, Original Equipment Manufacturers (OEM), additive companies and pump manufacturers to develop a test method and performance limit for fuel lubricity. The resultant method, the High Frequency Reciprocating Rig (HFRR, ISO 12156) procedure, is a bench test that provides good correlation to measured pump effects. To secure the durability of fuel injection system components, it is recommended that the measured wear scar in the HFRR test should not exceed 460 microns.

Appendix 3

Housekeeping

1. The problems encountered by vehicles from poor quality fuel are often caused by adulteration that occurs in the fuel distribution system, after the fuel has left the refinery gate. Failure to invest in adequate pipeline and storage facilities and failure to maintain the equipment can lead to volatility losses, fuel leakage and contamination by particulates and water that, in turn, can lead to a host of other vehicle problems. Excess levels of water, for example, will lead to corrosion. Poor operating practices at the service station, such as too infrequent replacement of fuel dispenser filters or "dipping" of tanks to check for water, can magnify these problems. CEN has issued a useful guideline document on good practice for fuel house keeping: CEN TR 15367."