

**Proposal for a guideline to be added  
to the Consolidated Resolution on the Construction of Vehicles (R.E.3)**

Insert a new Annex X, to read:

**"X. MARKET FUEL QUALITY GUIDELINE**

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

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**2. Purpose of the recommendation**

This Recommendation is intended to inform governments about appropriate market fuels for achieving desired vehicle emission requirements and to promote harmonisation of market fuel quality to facilitate use of the necessary emission control technologies. This Recommendation is mainly addressed to countries which are contemplating 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.

**3. Scope of the recommendation**

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

#### **4. Definitions and Abbreviations**

[As necessary]

#### **5 Introduction**

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.

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 recognised 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.

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, in order to keep the recommendation updated with the technical progress.

#### **6. Fuel Quality Recommendations**

## 6.1 Gasoline quality

Gasoline parameters <sup>1</sup>	Euro 2 emissions enabling fuel <sup>2</sup>	Euro 3 emissions enabling fuel <sup>3</sup>	Euro 4 emissions enabling fuel <sup>4</sup>	Test method
Sulphur (mg/kg or ppm)	≤ 500	≤ 150	≤ 50 <sup>5</sup>	EN ISO 20846 EN ISO 20884
Lead <sup>6</sup> (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 <sup>7</sup> (mg/l)	no intentional addition	no intentional addition	no intentional addition	ICP or ASTM D 7111
Iron <sup>8</sup> (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 <sup>9</sup> (% m/m)				EN 1601 EN 13132
Oxygenates (% v/v) - methanol - ethanol <sup>10</sup>				EN 1601 EN 13132
RVP (kPa)				EN 13016/I DVPE
RON (-) <sup>11</sup>				EN ISO 5164
MON (-) <sup>12</sup>				EN ISO 5163

<sup>1</sup> See Annex 1 and Annex 3

<sup>2</sup> See UN-ECE R.83.03

<sup>3</sup> See UN-ECE R.83.05 (row A)

<sup>4</sup> See UN-ECE R.83.05 (row B)

<sup>5</sup> Clarify the footnote: UNEP decision taken at the 4th global PCFV meeting, 14 - 15 December 2005 at UNEP Headquarters in Nairobi, Kenya. See Annex 1, Sulphur

<sup>6</sup> Potassium-containing additives may be used in Lead Replacement Petrol (LRP). See Annex 1, Lead

<sup>7</sup> The European Commission 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

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

<sup>9</sup> The oxygen content and the vehicle technology must be fully compatible in order to ensure satisfactory vehicle performance and compliance with emissions standards. See Annex 1, Oxygen

<sup>10</sup> The ethanol content and the vehicle technology must 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 (ASTM D 4806). See Annex 1, Oxygen and Oxygenates

<sup>11</sup> Add footnote on the relevance of RON to emissions performance. See Annex 1, RON

<sup>12</sup> Add footnote on the relevance of MON to emissions performance. See Annex 1, MON

## 6.2 Diesel fuel quality

Diesel fuel parameters <sup>13</sup>	Euro 2 emissions enabling fuel <sup>14</sup>	Euro 3 emissions enabling fuel <sup>15</sup>	Euro 4 emissions enabling fuel <sup>16</sup>	Test method
Sulphur (mg/kg)	≤ 500	≤ 350	≤ 50 <sup>17</sup>	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 <sup>18</sup>				EN ISO 5165
Cetane Index <sup>19</sup>				EN ISO 4264
Density (kg/m <sup>3</sup> ) at 15°C				EN ISO 3675 EN ISO 12185
Viscosity <sup>20</sup> (mm <sup>2</sup> /s)				EN ISO 3104
Flash Point (°C)				EN ISO 2719
FAME <sup>21</sup> (% v/v)				EN 14078
Lubricity <sup>22</sup> (microns)				ISO 12156-1

<sup>13</sup> See Annex 2 and 3

<sup>14</sup> See UN-ECE R. 83.03 and R. 49.02 (Stage II)

<sup>15</sup> See UN-ECE R. 83.05 (row A) and R. 49.03 (row A)

<sup>16</sup> See UN-ECE 83.05 (row B) and R. 49.03 (row B1)

<sup>17</sup> Clarify this footnote as per the corresponding gasoline footnote: UNEP decision taken at the 4th global PCFV meeting, 14 - 15 December 2005 at UNEP Headquarters in Nairobi, Kenya. See Annex 2, Sulphur

<sup>18</sup> Add footnote on relevance of Cetane number and country limits. See Annex 2, Cetane number

<sup>19</sup> Add footnote on relevance of Cetane index and country limits. See Annex 2, Cetane index

<sup>20</sup> Add footnote to reference CEN/ASTM limits (for example) See Annex 2, Viscosity

<sup>21</sup> The FAME concentration and specifications and the vehicle technology must 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 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 (ASTM D 6751). NOTE: Add prevailing country limits as was done in the ethanol section (Explanatory Annex 1). See Annex 2, FAME

<sup>22</sup> 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

**7. References**

[if necessary]

**8. Annexes**

## **Annex 1**

### **Gasoline properties**

#### **Sulphur**

Sulphur naturally occurs in crude oil. Sulphur has a significant impact on vehicle emissions by reducing 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.

There has been extensive testing done on the impact of sulphur on vehicle emissions. Studies such as those performed by AQIRP in USA, Auto-Oil programs in Europe and JCAP in Japan have shown significant emission reductions with different vehicle technologies as sulphur is

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

#### **Lead (TEL)**

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 must 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.

#### **Manganese (MMT)**

MMT (methylcyclopentadienyl manganese tricarbonyl) 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.

- 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 expense for consumers and vehicle manufacturers.
- 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.

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.

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.

### **Iron (Ferrocene)**

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% 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.

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.

### **Phosphorus**

Phosphorous affect negatively the catalyst performance by blocking the catalytic sites.

### **Potassium, Sodium**

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

### **Oxygen and Oxygenates**

(to be included later)

### **Vapor Pressure (RVP, DVEP)**

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 must 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.

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. Vapor pressure requirements for market gasolines should be set strictly in accordance with climatic and seasonal demands.

### **Octane (RON, MON)**

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.

Vehicles are designed and calibrated for a certain octane values, to cover all possible driving conditions. When a customer 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. Gasolines with adequate octane ratings, covering the requirements of the whole vehicle fleet (see vehicle handbooks), should be available in all world markets



## **Annex 2**

### **Property of diesel**

#### **Sulphur**

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 level increases, relative engine life decreases as a result of increased corrosion and wear of the engine components.

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<sub>2</sub>, which is the primary sulphur compound emitted from the engine. Some of the SO<sub>2</sub> is further oxidised to sulphates (-SO<sub>4</sub>). The sulphates and associated water coalesces around the carbon core of the particulates, which increases the mass of the PM. Thus fuel sulphur has a significant influence on the measured PM emissions.

For non-catalyst vehicles, the conversion of SO<sub>2</sub> 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 have a significant impact on the efficiency and durability of the vehicle after-treatment system.

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

#### **Ash**

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.

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.

#### **Total Contamination**

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 2000 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.

### **Water**

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.

### **Cetane, Number and Index**

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

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 the cetane number when the fuel does not contain cetane improver).

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 programs, for instance EU Auto-Oil, have confirmed that higher cetane numbers will improve also the NOx emissions, particularly in Heavy Duty engines.

### **Density and Viscosity**

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.

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

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.

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

### **FAME**

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 GHG (CO<sub>2</sub>) reduction ambitions for the transport sector.

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.

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 organization (CEN) has published 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)

Generally, biodiesel enhances the lubricity of conventional diesel fuel and reduce 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.

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

- 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 suggest such problems may be exacerbated when biodiesel is blended with ultra-low sulphur diesel fuels.
- 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.
- Being hygroscopic, biodiesel fuels require special handling to prevent high water content and the consequent risk of corrosion and microbial growth.
- 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.
- 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. Transitioning 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 must be specially chosen for their compatibility with biodiesel.

A useful handling guideline for FAME and FAME blends has been published by Concawe (<http://www.concawe.be/DocShareNoFrame/Common/GetFile.asp?PortalSource=1856&DocID=22269&mfd=off&pdoc=1>)

### **Lubricity**

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.

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.

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, OEMs, 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.

## **Annex 3**

### **House Keeping**

The problems encountered by vehicles from poor quality fuel often are 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 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

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