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Input for a revision of the THC and methane (CH_4) emission limits for vehicles equipped with engines running on natural gas (Euro 6 Light Duty Vehicles and Euro VI Heavy Duty Engines)

From the GRPE Informal Group on Gaseous Fuelled Vehicles (GFV)

Introduction

European law specifies limit values (and test methods) for pollutant emissions from light duty vehicles and heavy duty engines including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOx) and particulates, which are considered dangerous to human health. Carbon dioxide (CO_2) is not considered as a pollutant or as a dangerous emission affecting human health but, as a greenhouse gas, is a contributor to global warming. In this respect CO_2 is not specified as a criteria pollutant of an individual vehicle, however, CO_2 limits are specified for automobile manufacturers' 'fleet' of production vehicles by EU Regulation 443/2009 (Performance Standards for Passenger Cars to Reduce CO_2 Emissions for LDVs) and in 510/2011 (covering CO2 emissions from light duty commercial vehicles).

Historically, emission regulations focused only on diesel and petrol vehicles, specifying limit values for hydrocarbons and NO_X, mostly due to concerns about smog and ozone formation in the atmosphere. With the introduction of natural gas vehicles (NGVs), it was necessary to distinguish between the total hydrocarbon emissions and methane (CH_4) emissions. Unlike non-methane hydrocarbon emissions (NMHC), (and non-methane organic gas (NMOG) emissions regulated in N. America), methane does not react with NOx in the presence of sunlight to form airborne particulate and ground level ozone. Methane is, however, a greenhouse gas.

The current Euro 6 light duty vehicle emission limits for total hydrocarbons (THC) include the methane fraction as well as non-methane hydrocarbon emissions. When the Euro 5/6 co-decision proposal was negotiated, an NMHC limit value was added but the THC limit remained. The basic argument was that methane is a strong greenhouse gas. Unfortunately, the limit value of THC was not changed, therefore, it remained too restrictive for natural gas vehicles. Expensive methane catalysts are needed to convert this CH_4 into another greenhouse gas, CO_2, with very little environmental benefit due to the dominant amount of CO_2 present in the exhaust emissions. Ultimately, however, It would be more appropriate and logical to add methane to the CO_2-equivalent emissions of a vehicle.

In this respect the methane emission could not yet be completely deleted from the limit table before the CH_4 emission is added as a CO_2 equivalent emission to the automotive CO_2 Regulations 443/2009 and 510/2011. This is the reason why we propose a two step approach:

1) Align the HC requirements of the Light Duty Regulation 715/2007 with the NMHC requirements contained in the Heavy Duty Regulation 595/2009

2) Delete CH_4 from the table of limit values for all vehicles (light duty and heavy duty)

Step 1. Align the HC requirements of the Light Duty Regulation 715/2007 with the NMHC requirements in the Heavy Duty Regulation 595/2009

This first step would delete the THC limits and instead introduce a methane (CH_4) limit (or 'cap') that recognizes political concerns of global warming but that is at a level achievable by the best available NGV technology. The approach uses the heavy duty regulation's ratio between CH_4 and NMHC as the guiding factor: 3,125 (500/160). Using this same ratio the LDV emission limits would be as follows:

		Reference mass (RM) (kg)	Limit values													
			Mass of carbon monoxide (CO)		Mass of methane (CH_4)		Mass of non-methane hydrocarbons (NMHC)		Mass of oxides of nitrogen (NOx)		Combined mass of hydrocarbons and oxides of nitrogen (THC + NOx)		Mass of particulate matter (PM)		Number of particles (P)	
			L_1 (mg/km)		L_2 (mg/km)		L_3 (mg/km)		L_4 (mg/km)		$L_2 + L_4$ (mg/km)		L_5 (mg/km)		L_6 (#/km)	
Category	Class		PI	CI	PI	CI	PI	CI	PI	CI	PI	CI	PI[1]	CI	PI[1][2]	CI
M	—	All	1000	500	212	—	68	—	60	80	—	170	5.0/4.5	5.0/4.5	6.0×10^{11}	6.0×10^{11}
N_1	I	RM ≤ 1305	1000	500	212	—	68	—	60	80	—	170	5.0/4.5	5.0/4.5	6.0×10^{11}	6.0×10^{11}
	II	1305 < RM ≤ 1760	1810	630	281	—	90	—	75	105	—	195	5.0/4.5	5.0/4.5	6.0×10^{11}	6.0×10^{11}
	III	1760 < RM	2270	740	337	—	108	—	82	125	—	215	5.0/4.5	5.0/4.5	6.0×10^{11}	6.0×10^{11}
N_2	—	All	2270	740	337	—	108	—	82	125	—	215	5.0/4.5	5.0/4.5	6.0×10^{11}	6.0×10^{11}

Step 2. Delete CH_4 from the table of limit values for all vehicles (light duty and heavy duty)

Step two would remove all CH_4 limits (caps) from the tables of light duty and heavy duty. This step presumes the European regulators ultimately will act to more appropriately adjust other CO_2 regulations to account for global warming emissions from all appropriate sources.

Light Duty Vehicles

Create light duty vehicle limit values without CH_4 (delete CH4 column). In order to better align the other emissions with heavy duty vehicles as well as the final OBD thresholds the same columns are used as for the OBD thresholds. The combined THC + NOx column is deleted and a new NMHC limit is introduced for CI engines. The new NMHC limits are calculated from the final OBD threshold limits (see Annex I) with the condition that the NMHC limits will not be higher than the existing THC limits (category M: THC = NMHC = 100 mg/km).

		Reference mass (RM) (kg)	Limit values									
			Mass of carbon monoxide (CO)		Mass of non-methane hydrocarbons (NMHC)		Mass of oxides of nitrogen (NOx)		Mass of particulate matter (PM)		Number of particles (P)	
			L_1 (mg/km)		L_3 (mg/km)		L_4 (mg/km)		L_5 (mg/km)		L_6 (#/km)	
Category	Class		PI	CI	PI	CI	PI	CI	PI[1]	CI	PI[1][2]	CI
M	—	All	1000	500	68	**100**	60	80	4.5	4.5	6.0×10^{11}	6.0×10^{11}
N_1	I	RM ≤ 1305	1000	500	68	**100**	60	80	4.5	4.5	6.0×10^{11}	6.0×10^{11}
	II	1305 < RM ≤ 1760	1810	630	90	**110**	75	105	4.5	4.5	6.0×10^{11}	6.0×10^{11}
	III	1760 < RM	2270	740	108	**120**	82	125	4.5	4.5	6.0×10^{11}	6.0×10^{11}
N_2	—	All	2270	740	108	**120**	82	125	4.5	4.5	6.0×10^{11}	6.0×10^{11}

Heavy Duty Vehicles

Heavy duty vehicle limit values without THC and CH_4. (NH_3 under discussion so NH_3 is shown between brackets [ ])

	Limit values					
	CO (mg/kWh)	NMHC (mg/kWh)	NO_X [1] (mg/kWh)	NH_3 [ppm]	PM mass (mg/kWh)	PM [2] number (#/kWh)
WHSC (CI)	1500	130	400	[10]	10	$8{,}0 \times 10^{11}$
WHTC (CI)	4000	160	460	[10]	10	$6{,}0 \times 10^{11}$
WHTC (PI)	4000	160	460	[10]	10	[3]

RATIONALE

METHANE EMISSIONS & NATURAL GAS VEHICLES

Natural gas vehicles (NGVs) have an undisputed role to play in reducing emissions in the transportation sector. When used in light duty or heavy duty vehicles, natural gas the fossil fuel (predominantly methane – CH_4) and renewable biomethane result in reduced emissions of almost all regulated and non-regulated emissions compared to gasoline and diesel-fuelled vehicles possibly with one exception: total hydrocarbons.

Though NGVs are able to reduce ozone-forming, reactive hydrocarbon emissions by 85% over a typical, current generation petrol vehicle, the total hydrocarbon (THC) emissions of NGVs *tend* to be higher than the emissions limit values in European emission directives, also which are mirrored in United Nations Regulations (UNECE). Though methane is a recognized global warming gas, current generation NGVs reduce global warming emissions over current generation gasoline cars by 20-25%. In the scope of global methane emissions from natural sources and manmade (anthropogenic) sources, the methane output of even millions of NGVs on the road is in the one thousandth of a percentage increase of the overall worldwide output of methane. Thus, the environmental damage of NGV methane (or CO2) emissions is far outweighed by their emissions benefits.

BACKGROUND/HISTORY TO REGULATORY TREATMENT OF METHANE, NMHC, AND THC

First Steps Internationally to Eliminate a THC in Favor of an NMHC

A non-methane hydrocarbon (NMHC) emission limit value for light and heavy duty vehicles was adopted in the U.S. Clean Air Act Amendments of 1990 due to the advocacy efforts of the NGV industry. California regulated NMOG shortly thereafter, as did the U.S. Environmental Protection Agency (EPA). In Japan, where there is a growing population of mostly factory-made NGVs, hydrocarbons are measured as NMHC since 2005.

The European Regulatory Approach to Methane, NMHC and THC Has Been Inconsistent

In Europe, with the introduction of gaseous fuelled vehicles, an NMHC emission limit value specific for gas vehicles also was recognized for heavy duty vehicles in 1999 in an amendment (1999/96/EC) to Directive 88/77/EEC. A specific methane limit value also was introduced for natural gas vehicles.

Methane was defined as a *pollutant* in the European Directive on Emissions Requirements for Heavy Duty Vehicles (88/77/EEC amended by 1999/96/EC). This could be seen as contradicting the original European Council Directive 96/62EC on Ambient Air Quality Assessment and Management, which listed 13 pollutants but not methane. As such, it became possible to legally regulate methane emissions since methane was identified as a contributor to global warming. This lead to the establishment of a methane emissions limit value for vehicles. The Euro 5/6 regulations include a non-methane hydrocarbon (NMHC) emissions limit value of 68 mg/km, however, the THC limit value of 100 mg/km was maintained from the Euro 4 limit which, practically, negates the purpose of having an NMHC limit value for NGVs.

A Contradiction in Implementation

The On-Board Diagnostics (OBD) regulations in Europe (as in North America) call for compliance with NMHC limit values but ***not*** THC limits. As such, it is inconsistent to have a THC limit value that cannot be detected in an OBD system. The OBD system detects when NMHC limits are exceeded but never detects when THC limits are exceeded. When a fault occurs with fuel trim, for example, the excessive HC emissions are based on measuring NMHC only because that is what is specified in the regulations. In other words, CH_4 is not part of the OBD fault detection system.

It is important to detect a fault when it occurs in the emission control system, which will cause emissions to exceed the regulated limit values. So it is apparent that there is no *practical* interest in detecting when CH_4/THC emissions exceed the limit values because CH_4 is not a criteria pollutant causing smog formation. The malfunction indicator lamp (MIL) will be set when the NMHC emission limits are exceeded, which will set lower than the THC limit, so the THC limit value becomes irrelevant. Only NMHC emissions are measured when setting the MIL thresholds. Removing the THC limit value will align the regulations with the ability of the OBD technology to detect when the regulated emissions limits are exceeded.

IMPACTS ON NGVS OF MEETING A THC LIMIT VALUE

The gasoline car engines that have to meet the 0.1 g/km THC limit imposed at first in EURO 4, and now also in EURO 5 and EURO 6 limits, use catalysts with a content of precious metals (platinum, palladium, rhodium), of about 50 g/ft^3 (normal), or 80-to-120 g/ft^3 (high performance), that convert the THC emissions (in this case composed by more than 90% of NMHC) into their basic components, CO_2 and H_2O. When designing CNG dedicated, mono-valent or bi-fuel vehicles, OEMs have to use special catalysts with a far higher content of precious metals, from 150-to-200 g/ft^3, up to 300 g/ft^3, to be able to limit the THC emissions (which in this case means more than 90% methane), at the level of 0.1 g/km.

Meeting the THC limit imposes significant additional costs that do not translate into a net environmental benefit. Methane catalysts have been added to factory-built NGVs (cost ranges from manufacturers are in the €200-€400 Euro range) but this increases the cost of the vehicle at a time when the industry is trying to make NGVs more economically attractive for customers. For the retrofit sector, which comprise roughly 90% of the 14.5 million NGVs worldwide, the added cost of compliance with a THC limit can prevent these vehicles from coming into the market. In either case, factory made or aftermarket retrofit, the marginal improvement in methane emissions (and global warming potential) is so infinitesimal that the requirement to add a methane catalyst on a vehicle to meet the THC standard defies scientific and policy logic.

Since EU legislation has a strong and direct impact on UN regulations, Contracting Parties to UN treaties would be subject to the same requirements. Other countries use UN regulations as a model for their national regulations. Hence, a regulatory solution is required that can both meet the needs of environmental control yet does not increase the cost of the vehicles nor force out of business many of the suppliers of the world's NGVs from countries that use UN emissions regulations as models for their national regulations.

A TWO STEP SOLUTION TO THE PROBLEM

Ultimately the concerns of policy makers and regulators about global warming could lead to treating all greenhouse gas emissions in the same regulatory 'basket'. This issue is valid for all vehicles and appropriate to add the CH_4 emissions to the automotive CO_2 regulation 443/2009. Of course this is a topic with contentious political ramifications and will take some time to resolve and implement.

The European Commission has suggested replacing Article 14(1) of Regulation 715/2007/EC by the following text:
" The Commission may, without lowering the level of environmental protection, in accordance with the regulatory procedure with scrutiny referred to in Article 15(3) and on the basis of an impact assessment, account the greenhouse gas effects of methane emissions as CO_2 equivalents in vehicle type approval information and accordingly increase or remove limit values of THC emissions of positive ignition vehicles."

In support of the Commission's efforts the GFV is, therefore, advocating a fair and practical regulation that responsibly accounts for NGV methane emissions without penalizing the vehicles that run on the fuel. The approach incorporates two steps that solves the THC/NMHC issue yet provides a temporary solution for the NGV industry.

Step 1) Align the HC limit requirements in the Light Duty Regulation 715/2007 (Type Approval of Motor Vehicles with respect to emissions from light passenger cars and commercial vehicles [Euro 5 and 6]) with the Heavy Duty Regulation 595/2009 (Type Approval of Motor Vehicles with respect to emissions from heavy duty vehicles [Euro VI]).

This first step would delete the THC limits and instead introduce a methane (CH4) limit (or 'cap') that recognizes political concerns of global warming but that is at a level achievable by the best available NGV technology. The approach uses the heavy duty regulation's ratio between CH_4 and NMHC as the guiding factor: 3.125 (500/160).

Step 2) Delete CH_4 from the table of limit values from all vehicles (light duty and heavy duty)

Step two would remove all CH_4 limits (caps) from the tables of light duty and heavy duty. This step presumes the European regulators ultimately will act to more appropriately adjust other emissions directives to account for global warming emissions from all appropriate sources.

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ANNEX 1

Table of final Euro 6 OBD thresholds, emissions limits and the calculated factors (OBD / emission = *factor*)

			Reference mass (RW) (kg)	Mass of carbon monoxide (CO) (mg/km)		Mass of non-methane hydrocarbons (NMHC) (mg/km)		Mass of oxides of nitrogen (NOx) (mg/km)		Mass of particulates (PM) (mg/km)		Number of particles[1] (PN) (#/km)	
	Category	Class		PI	CI[2]	PI	CI[2]	PI	CI	CI	PI	CI	PI
OBD	M	—	All	1900	1750	170	290	90	140	12	12		
emission				1000	500	68	100	60	80	4,5	4,5		
factor				1,9	3,5	2,5	2,9	1,5	1,75	2,7	2,7		
OBD	N_1[3]	I	RW ≤ 1305	1900	1750	170	290	90	140	12	12		
emission				1000	500	68	100	60	140	4,5	4,5		
factor				1,9	3,5	2,5	2,9	1,5	1,75	2,7	2,7		
ODB		II	1305 < RW ≤ 1760	3400	2200	225	320	110	180	12	12		
emission				1810	630	90	110	75	105	4,5	4,5		
factor				1,9	3,5	2,5	2,9	1,5	1,75	2,7	2,7		
ODB		III	1760 < RW	4300	2500	270	350	120	220	12	12		
emission				2270	740	108	120	82	125	4,5	4,5		
factor				1,9	3,4	2,5	2,9	1,5	1,75	2,7	2,7		
OBD	N_2	-	All	4300	2500	270	350	120	220	12	12		
emission				2270	740	108	120	82	125	4,5	4,5		
factor				1,9	3,4	2,5	2,9	1,5	1,75	2,7	2,7		