DISCUSSION DRAFT

RATIONALE FOR THE DEVELOPMENT OF A NON-METHANE HYDROCARBON REGULATION FOR NATURAL GAS VEHICLES

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The Necessity to Develop a Non-Methane Hydrocarbon Emissions Limit Value for 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 – CH4) 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 natural gas vehicles (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 an NGV *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 NGVs methane (or CO2) emissions is far outweighed by their emissions benefits.

The new 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 an NMHC limit value for NGVs. These limit values also will serve as the basis of third countries use of UNECE regulations. Unless an NMHC is recognized without the imposition of a separate THC limit value, the result of this action is that many NGVs, and particularly aftermarket (retrofit) conversions of petroleum vehicles that represent at least 90% of the 9 million NGVs worldwide, functionally can be prevented from entering the market or be excluded from various national fiscal incentives established for so-called clean cars.

It is common knowledge that the methane conversion efficiency of present day three way catalysts is not as good as expected or desired. To meet the Euro-4, 5 or 6 THC limits without excessive petrol running time (for bi-fuel vehicles), NGV-manufacturers have already adopted sophisticated and costly solutions. Meeting the THC limit will impose significant additional costs that do not translate into a net environmental benefit. Expensive 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. In either case, factory made or aftermarket retrofit, the marginal improvement in methane emissions 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 force out of business the bulk of the suppliers of the world's NGVs.

Background/history to the Development of a European NMHC

The European NGV industry has, since 1995 advocated the creation of a separate NMHC emission limit value for light duty and heavy duty vehicles in European emission regulations, which also become the basis of emissions regulations in UNECE.

First Step in the EU to Create an NMHC

An NMHC emission limit value for light and heavy duty vehicles was adopted in the U.S. Clean Air Act Amendments of 1990. California regulated non-methane organic gases (or NMOG) shortly thereafter and, since 2005, Japan hydrocarbons are measured as NMHC. An NMHC emission limit value also was recognized (but not mandated) in Europe for heavy duty vehicles in 1999 in an amendment (1999/96/EC) to Directive 88/77/EEC but with the difference that still THC also was regulated. (The NMHC was incorporated as part of the Environmentally Enhanced Vehicle (EEV) *target standard* but not regulated as such.

The European Commission (EC) in 1999 was ready to amend the Light Duty Vehicle Euro 3/4 emissions Directive 70/220/EEC (99/102/EC) like the Heavy Duty Vehicles at the Motor Vehicle Emissions Group in Brussels but, at the last moment of consideration, the Commission proposal was opposed by one Member State due to the fact that one car manufacturer had achieved the THC standard using, at that time, a unique, expensive methane catalyst. The Commission withdrew its proposal on NMHC.

The EU Regulates Methane as a Pollutant

Methane (CH4), the main constituent in natural gas, is an inert, naturally occurring substance that is one of the fossil fuels created over the millennium from deterioration of organic substances. Biogas can be manufactured as a renewable energy source from a variety of materials including agricultural waste products, sewage or urban garbage. ('Raw' biogas then can be upgraded to 'biomethane' for use as a high premium fuel in natural gas vehicles.) Methane is not a product of combustion nor is it a product of a chemical reaction. Methane is not a health endangering substance but it is, on the other hand, a greenhouse gas.

The original European Council Directive 96/62EC on Ambient Air Quality Assessment and Management listed 13 pollutants, but not methane. But in 1999 methane was defined as a *pollutant* by the European Directive of emissions requirements of Heavy Duty Vehicles (88/77/EEC amended by 1999/96/EC). As such it became possible to legally regulate methane emissions since it is considered as a contributor to global warming.

In contrast to the European approach to methane, the U.S., the Clean Air Act Amendments of 1990 (Public Law 101-549) includes a list of ***190*** *hazardous pollutants*

but not methane. According to the definition of a pollutant, “A poisonous chemical harmful to the health of living creatures and plants”, methane is not a pollutant.

Both CO2 and methane are, however, due to their *physical* characteristics, considered as greenhouse gases. When the European Union legislated methane as a pollutant it lead to the establishment of methane emissions limit for vehicles. In terms of a total hydrocarbon (THC) regulation, this now presents a distinct barrier to the NGV commercialization effort. Ironically, vehicle manufacturers did not want CO2 listed as a pollutant or otherwise regulated. It is a policy paradox that the EU identifies only methane emissions from NGVs as a global warming pollutant and fails to put CO2 in the same legislative/regulatory category.

Methane Sources & Its Impact on the Environment

Methane (CH_4), as a non-toxic substance, has traditionally been thought to have a negligible contribution to ozone formation compared to other hydrocarbons (NMHCs). Methane is not reactive in sunlight to create ozone and, as such, has not generally been considered to be a major ozone contributor at the tropospheric level. Methane’s contribution to stratospheric ozone, in fact, has been considered a benefit in light of other ozone-destructive gases such as chlorofluorocarbons (CFCs), which have been identified as creating a ‘hole’ in the upper atmospheric ozone layer. This allows additional sunlight to hit the earth’s surface, thus contributing to the overall warming effect.

Findings from experts about atmospheric impacts sometimes are in conflict

The vast wealth of atmospheric chemistry analyses and modelling has resulted in a wide range of findings and conclusions about the effect of methane in the atmosphere and its relationship and reaction with other emissions. It is clear, however, that:

- The global world emissions of CH_4 from natural origin (wetlands, rice fields, termites, ocean, hydrates), and from anthropogenic origin (energy, landfills, ruminants, waste, biomass burning), is calculated to be 600 million tons/year (TgCH4/year). (Wuebbles 2002/IPCC 1995/US EPA)
- One of the main ‘sinks’ for destroying atmospheric methane is hydroxyl radicals (OH) found in abundance in the atmosphere, particularly in the troposphere.
- OH accounts for absorbing/destroying approximately 500 TgCH4/year, about 85%-90% of worldwide methane emissions in the troposphere.
- About 30 TgCH4/year, or about 5% is removed through dry soil oxidation.
- About 7% of global methane is transported to the stratosphere (IPCC 1996/Wuebbles).
- About 10% of the total ozone exists in the troposphere.

In 2006 a paper by, West, Fiore, et.al., *“Global Health Benefits of Mitigating Ozone Pollution with Methane Emissions Controls,”* claimed that methane is a precursor to ozone in the troposphere and that ozone is a factor in premature deaths worldwide. It modelled premature deaths using other methane research that focused on methane emissions from five industrial sectors: coal production, oil, natural gas operations, landfills and wastewater treatment, which account for about 29% of worldwide annual

methane emissions (National Oceanic and Atmospheric Administration [NOAA], U.S. EPA)

The authors stated, "Methane abatement has been considered a low-cost means of addressing climate change, particularly to influence the short-term rate of climate change. However, CH4 abatement has not been considered for air quality management mainly because ozone (O3) pollution has traditionally been considered a local and regional problem, and the local benefits of local CH4 reductions are small."

The work of West/Fiore, et.al. was embraced by the European Commission and reproduced in a briefing paper, *Science for Environment Policy* by Directorate General (DG) Environment News Alert Service, 30 March 2006, titled, after the West study, *"Mitigating Ozone Pollution with Methane Emission Control."* The DG Environment briefing paper highlighted the main theme of West/Fiore:

"A recent research has explored the impact of methane mitigation on the atmospheric levels of ozone, an air pollutant associated with premature mortality. The results show that a 20% reduction of current methane emissions that could be achieved by 2010 could prevent up to 30,000 premature mortalities globally in 2030."

Since then, the EC, and DG Environment in particular, has questioned more vigorously the NGV industry attempts to establish an NMHC. Unfortunately, West/Fiore, et.al. has been the only study of its type linking methane to tropospheric ozone and ozone to mortality. The authors state, however, "Important uncertainties in this study lie in the relationship between O3 and mortality, and between CH4 emissions and global surface O3 concentrations."

From a policy perspective, the influence of methane as a global warming gas has resulted in some harmful regulatory decisions related to NGVs and their contribution to methane in the atmosphere. In Europe, the notion of methane as a contributor to tropospheric ozone based upon conclusions of one small set of U.S. analysts has provided a further reluctance in developing an NMHC regulation. The fact that NGVs are a minor contributor to overall global atmospheric methane has been overshadowed by political and not scientifically-based concerns about methane as an ozone precursor and as a major potential contributor to global warming.

Wuebbles/Hayhoe draw similar conclusions about known methane science and government policy stating that, "The atmospheric concentration of methane has increased dramatically over the last century and continues to increase. While budget and isotopic analyses have confirmed the important role being played by human activities in largely causing this increase, there remain significant uncertainties in understanding the emissions from various sources and their changes over time. The uncertainties in the changes occurring in the sources and sinks of methane limit the ability to determine meaningful policy relating to methane with respect to concerns about climate change."

NGVs' Contribution to Methane in the Atmosphere

NGVs contribute a fraction of atmospheric methane compared to natural and anthropogenic sources of CH_4

In an NGV, small volumes of methane pass unburned through the engine and the exhaust treatment system. Compared to the 600 TgCH4/year of methane emitted by natural and anthropogenic sources, the global emission of methane that could be reasonably expected from the NGV sector is negligible. To put it in perspective, worldwide there are about 9 million NGVs compared to 891 million petroleum-fuelled vehicles (or 0.1%). Sixty million vehicles running on natural gas/biomethane, or about 7% of the world total vehicle population, would produce roughly 120,000 tons of methane. (This is based on the present 100 mg/km emission rate of a single vehicle of which, in the case of NGVs is composed of more than 90% methane, and an average yearly mileage of 20,000 km/year; 20,000 km/year at 0.1 g/km methane emission.) On a global scale these methane emissions are infinitesimal – about 0.02% -- compared to all other methane emissions sources.

The use of methane catalysts on NGVs

- Most THC-emissions of NGVs and petrol vehicles are produced during cold-start, because the catalyst temperature first needs to reach the so-called "light-off" temperature before any HC-conversion takes place. NGVs without a petrol tank must start on natural gas; NGVs with a petrol tank can use algorithms that start the vehicle on petrol before switching to natural gas. Alternatively, NGVs with a petrol tank also can be designed to start on natural gas. The industry stresses that NGVs starting on natural gas, like the dedicated and more efficient mono-fuel vehicles without a petrol tank, will have great difficulty meeting a THC limit of 0.1 g/km. The same is valid also for an NGV with a petrol tank that is designed to start on natural gas.

- As stated above, the methane conversion efficiency of present day three way catalysts is not as good as expected or desired, however, no real catalyst improvement seems to be available in the near future. Catalyst suppliers have not made many efforts to improve this situation considering that, by definition, methane is not noxious.

- 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. This makes the new NGV models meeting the EURO 4/5/6 limits more expensive than they were in the past.

Other methane reduction strategies in NGVs

- To further improve the environmental performance of NGVs there is a general desire to reduce the time that NGVs have to run on petrol during the cold start phase. Meeting a THC limit of 0.1 g/km can be done by increasing the time the engine runs on petrol after start-up. This, however, leads to higher emissions of NMHC (and all unregulated components included in that), and thus leads to a net deterioration of the environmental performance.
- In addition, it is worth mentioning that OEMs currently are evaluating and developing the capabilities of CNG turbo charged engines in order to further improve fuel efficiency and reduce CO_2-emissions. For this technology catalyst light off will be further delayed due to the extra mass upstream of the catalytic converter.
- To meet the present THC limits without excessive petrol running time, NGV-manufacturers have already adopted sophisticated and costly solutions but that do not translate into a net environmental benefit. In this context it must be noted that a sharpened durability demand in Euro 5/6 (going from 80.000 to 160.000 km) will, in itself, mean a much tougher demand than the present Euro 4 limits.

Summary and Conclusions

- *Methane as an ozone precursor.* The generally accepted thinking about ozone in the troposphere is that only very small amounts, at best, can be attributed to methane. Most of the methane is either destroyed by OH and soil oxidation sinks or it is transported to the stratosphere.

- *NGVs contribution to atmospheric pollution.* Methane from NGVs is a fractional part of the overall methane emissions from natural or anthropogenic sources. Meanwhile, NGVs can reduce CO2 emissions over its petroleum-fuelled counterparts by 20-25%. Methane from renewable biogas can, on a well-to-wheel basis reduce CO2 emissions over petroleum-fuelled vehicles by 100-180% (Concawe, Eucar, JRC Well-to-Wheel study) NGVs dramatically reduce other emissions including particulates, NOx and CO.

- *European interests in establishing an NMHC.* It is to the advantage to adopt an NMHC in order to harmonize this feature of vehicle emissions regulations with the United States, California, and Japan.

- *Reducing general regulatory barriers.* Vehicle emissions regulations should be used to promote the improvement of atmospheric pollution, even if they are 'technology forcing.' Regulations that force technologies out of the market should not be adopted, particularly if it is proven that doing so reduces a market-ready, well established vehicle technology and clean fuel that can reduce emissions beyond that of petroleum (gasoline and diesel) fuelled vehicles.

- *Affects of European Regulations on Worldwide United Nations Regulations.* Because EU regulations are used as the basis for many United Nations vehicle regulations, it is important to make EU regulations as transparent as possible, designed to foster technology improvement and not limit promising clean fuel transportation options. As such, from a policy standpoint, it does not seem very sensible to run the risk of destroying the NGV retrofit market in order to avoid adding infinitesimally small amounts of methane into the atmosphere.

References

Wuebbles, Donald, J. and Katharine Hayhoe, *"Atmospheric Methane: Trends and Impacts,"* Department of Atmospheric Sciences, University of Illinois, Urbanba, Il, 2006.

West, Jason,J, Arlene M. Fiore, Larry W. Horowitz, and Denise L.Mauzerall, "*Global Health Benefits of Mitigating Ozone Pollution with Methane Emissions Controls,"* communication by James E. Hansen, Goddard Institute for Space Studies, New York, NY, January 11, 2006.

"Mitigating Ozone Pollution with Methane Emission Control," *Science for Environment Policy,* DG Environment News Alert Service, European Commission, 30 March 2006.

Concawe, Eucar, European Commission Joint Research Center, Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context, Version 2c, March 2007.

References for tables in the Annex I (below) are noted in the tables.

Annex I

Estimated Sources of Methane and Estimated Sinks of Methane (Wuebbles & Hayhoe). Houweling et al. (1999) give the following values for methane emissions (Tg/a=teragrams per year):

Table 1. (a) Estimated sources of methane, in Tg(CH_4)/yr and (b) Estimated sinks of methane, in Tg(CH_4)/yr (based on IPCC, 1995).

(a)

Source	Emissions (Tg(CH4)/yr)	range of estimate
Wetlands	115	55-150
Termites	20	10-50
Oceans	10	5-50
Other	15	10-40
Total Natural	160	110-210
Ruminants	85	65-100
rice cultivation	60	20-100
Total Agricultural	145	85-200
natural gas	40	25-50
coal mining	30	15-45
petroleum industry	15	5-30
coal combustion	15	1-30
biomass burning	40	20-80
waste disposal	90	55-180
Total Non-Agricultural Anthropogenic	215	145-380
TOTAL	535	410-660

(b)

Sink	Uptake (Tg(CH_4)/yr)	range of estimate
Tropospheric OH	445	360-530
removal to stratosphere	40	32-48
soil uptake	30	15-45
TOTAL	515	430-600

Global average methane concentrations from measurement (NOAA*)

Origin	**CH_4** emission		
	Mass Tg/year (million ton/year)	Type (%/a)	Total (%/a)
Natural Emissions			
Wetlands (incl. Rice agriculture)	225	83	37
Termites	20	7	3
Ocean	15	6	3
Hydrates	10	4	2
Natural Total	270	100	45

Anthropogenic Emissions			
Energy	110	33	18
Landfills	40	12	7
Ruminants (Livestock)	115	35	19
Waste treatment	25	8	4
Biomass burning	40	12	7
Anthropogenic Total	330	100	55
Grand total	600		100
*NOAA = National Oceanic and Atmospheric Administration			

U.S. Environmental Protection Agency