GFV-22-02

INFORMAL GROUP ON GASEOUS FUEL VEHICLES
Within the UN GRPE (WP29)

Name of Organisation submitting Amendment/Work Item
CLEPA : European Association of Automotive Suppliers

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Regulation name and reference number
Regulation 83

Name of Amendment/Work Item
Amendment to Regulation R83 and document ECE/TRANS/WP29/GRPE/201 regarding the use of petrol in gas mode and its limitation for bi-fuel gas vehicles and the verification during type approval.

Rationale: (Why is it important/required?)

Document "ECE/TRANS/WP29/GRPE/201" amends regulation R83 in view of the type approval of gas fuelled vehicles. The amendments are aimed at redefining the class of bi-fuel vehicles to permit the simultaneous use of gas and petrol in gas mode.
These modifications are needed primarily for the approval of some bi-fuel vehicles equipped with petrol direct injection systems, where, in order to safeguard the petrol injectors, a certain amount of petrol may need to be injected also in gas mode, especially when particular temperature conditions are reached.
In order to avoid over-employment of petrol, provisions are provided to limit its use in amount and duration.
A standard calculation method of the gas energy ratio is provided, based on a direct measurement of the gas consumption and a conservative calculation of the total energy consumed during the cycle.
In Appendix 1 and 2 of this document, a method is described to determine the amount of consumed fuel during the type 1 test by measuring the weight of an additional external fuel tank for the gaseous fuel (NG or LPG or H2). From the CLEPA point of view this procedure might lead to immense practical and safety problems during development and type approval. For that reason CLEPA proposes with this document an alternative method to the weighing procedure in order to determine the fuel consumption of petrol and the gaseous fuel in the test cycle. The CLEPA proposal should be added as an equivalent option to the regulation.

Justification

The test procedure described in ECE/TRANS/WP29/GRPE/201 was evaluated by automotive suppliers (CLEPA members) as well car manufacturer's test center departments and it was concluded, that the weighing of gas tanks may have practical and safety issues for several reasons.

- The additional and separate gas fuel tank which has to be stored in the test cell during type approval leads to safety problems. The gas tank has to be connected to the vehicle where gas leakages can occur during connecting or disconnecting. Then the test cell would be contaminated with additional HC background emission. In addition to that the risk of fire or explosions would occur.
- Current safety regulations do not allow the separate gas tank to stay in the test cell over night without observation.
- The fill up procedure before the test and the draining of the gas tank after the test can lead to very high efforts, as safety regulations do not allow the transport of unsecured gas tanks on public roads. The practical problem arises how to fill a small NG or LPG gas tank if no on-site refueling facility is available.
- The disconnection of NG/LPG fuel hoses from and to the vehicle presents a safety risk because especially for liquid LPG injection systems a high leakage rate can occur.
- LPG liquid fuel injection requires a fuel pump which is mounted inside the tank. Therefore, also a fuel pump has to be available inside the reference tank for weighing.
- The connection of hoses and tubes to the tank can lead to errors during weighing of the fuel tank, as it is difficult to determine the full weight of the hoses and tubes.
- Additional costs for the type approval for the tank installation, the weighing and safety equipment and continuous costs for maintenance will occur.

In order to prevent these practical and safety issues, an alternative method is proposed by CLEPA. With this method the fuel consumption (or fuel mass M_{petrol} and M_{gas} (NG or LPG or H_2)) is calculated by the ECU based on the injection time and flow rate through the fuel injectors. Usually, these values should be available in the ECU or in the additional gas control unit (GCU).

The integral fuel masses, calculated in a driving cycle after ignition key-on shall be provided to the Generic SCAN tool (J1979 / ISO 15031-5) as a new PID:

- The integral engine fuel consumption (FC) of M_{petrol} and of M_{gas} is calculated since ignition key-on in a resolution of 2 Byte, 0 …FFFF = 0 … 32769 g and a resolution of 0,5 g = 500 mg.
- The ECU internal resolution of FC accumulation shall be as high as the injection output in order not to miss any injected fuel quantity.
- The tolerance of the fuel consumption accumulation of the engine control unit shall be better than 3%.
- The update rate for M_{petrol} and of M_{gas} send to the scan tool shall be <=1 s.
- The integral fuel consumption is reset at ignition key-on event when the engine speed = 0 rpm.

As an example, figure 1 is showing a comparison of fuel consumption measurement (modal data) in the NEDC for a vehicle equipped with a mono-fuel CNG engine.
- Firstly the FC was determined by the exhaust gas measurement system using the CO_2 measurement data (carbon balance method) in the test center.
- Secondly the FC was calculated from the injected fuel mass in the engine control unit.
It can be seen, that the results from both measurement systems show the same behavior.

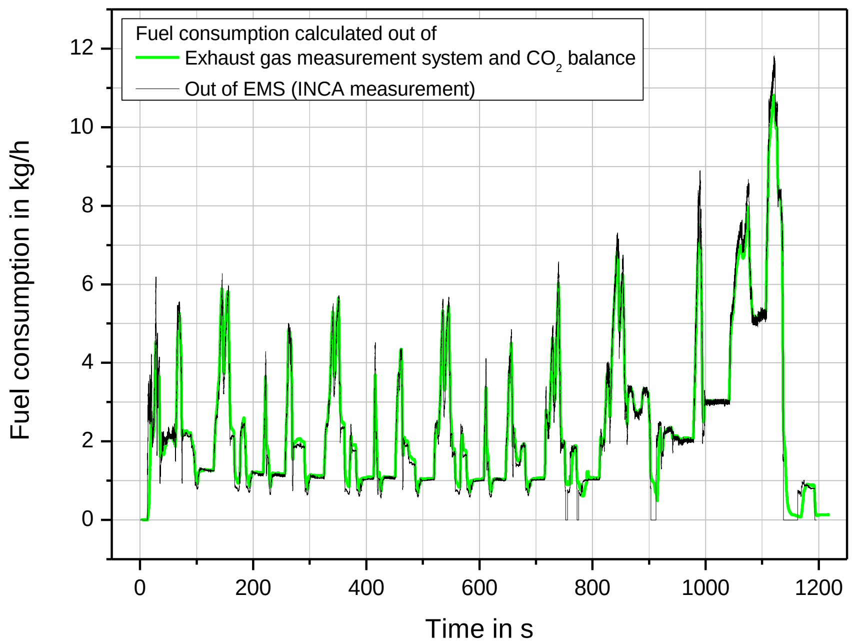

Figure 1: Comparison of fuel consumption measurement in the NEDC.

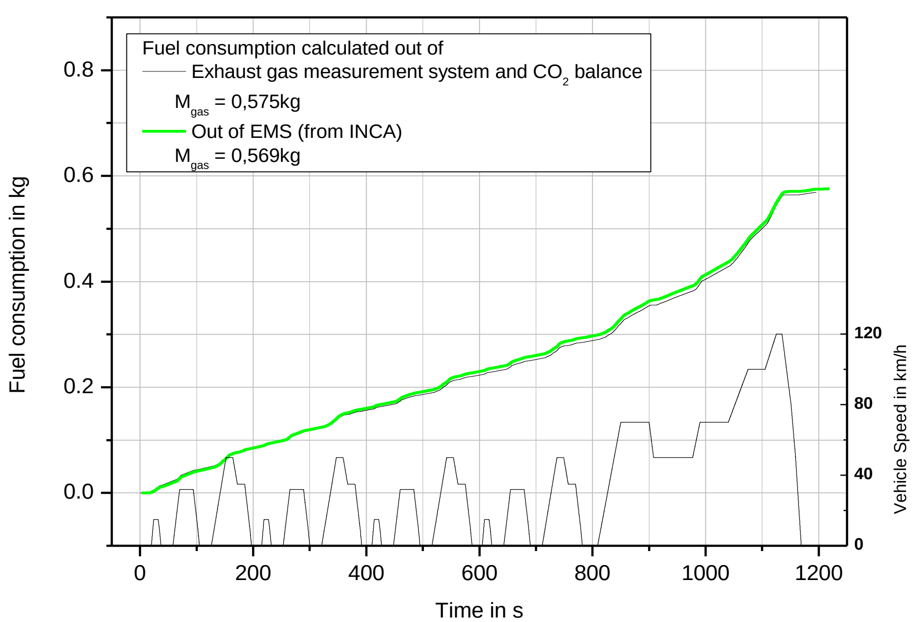

Figure 2: Integrated values of fuel consumption measurement in the NEDC.

In figure 2, the modal FC values in kg/h were integrated to a total FC in kg over the whole cycle. Here it can be seen, that the deviation is below 2% of the overall injected fuel mass.

Required Additional Efforts:

- A new PID has to be requested at the SAE J1979-community.
  (Note: All vehicles certified according to ECE-R83 have to support ISO 15031-5 = SAE J1979 "E/E Diagnostic Test Modes")
- The new PID has to be implemented into the ECU or the GCU only for gas fuelled vehicles

Advantages of the proposed method:

- No use and weighing of an external and separate gas tank (NG or LPG or H2).
- M_{Petrol} could be easily verified by comparison with the Fuel Consumption calculated based on the bag analysis (of a test run on petrol only).
- M_{Petrol} and M_{Gas} could be verified by calculation of resulting CO_2-Emission of M_{Petrol} and M_{Gas} and comparison with the CO_2- Emission based on the bag analysis.
- M_{Petrol} and M_{Gas} could be verified by comparison with the injection pulses: If there are pulses on both kinds of injectors, M_{Petrol} and M_{Gas} must increase.
- In principle the consumed NG and petrol mass values of the control unit could be read out continuously. The sum of the continuously converted fuel masses of both fuels to CO2 could be compared with the cumulated modal CO2 values from the CVS-System during a whole test cycle as shown in figure 1.

Verification of Fuel Consumption derived from the control unit with CO2 from bag analysis.
The fuel consumption M_{Petrol} and M_{Gas} given by the PIDs from the control unit can be recalculated into CO2 emissions which should fit to the CO2 emissions from the bag analysis

In ECE R101 the fuel consumption FC in the Unit [l/100km] is calculated as:

for vehicles with positive ignition engine for petrol *(E5)*:

$$FC = (\mathit{0{,}118}/D) \cdot [(\mathit{0{,}848} \cdot HC) + (0{,}429 \cdot CO) + (0{,}273 \cdot CO_2)]$$

for vehicles with positive ignition engine for NG*/Biomethane*:

$$FC_{norm} = (0{,}1336 / 0{,}654) \cdot [(0{,}749 \cdot HC) + (0{,}429 \cdot CO) + (0{,}273 \cdot CO_2)]$$

Recalculation into the Unit [kg/100km] leads to:

for vehicles with positive ignition engine for petrol *(E5)*:

$$FC = (\mathit{0{,}118}) \cdot [(\mathit{0{,}848} \cdot HC) + (0{,}429 \cdot CO) + (0{,}273 \cdot CO_2)]$$

for vehicles with positive ignition engine for NG*/Biomethane*:

$$FC_{norm} = (0{,}1336) \cdot [(0{,}749 \cdot HC) + (0{,}429 \cdot CO) + (0{,}273 \cdot CO_2)]$$

Considering that emissions of HC and CO are below the emission limit values of HC < 0,1g/km and CO <1g/km then the HC/CO - Emission part of the equations can be replaced by 0,749 * 0,1 + 0,429 * 1 = 0,5039 for the worst case for CNG and 0,848*0,1+0,429*1 = 0,5138 for the worst case for petrol. Therefore

$$FC_{Petrol} = 0{,}118 * (0{,}5138 + 0{,}273\ CO_2)\ [kg/100km]$$

$$FC_{Gas} = 0{,}1336 * (0{,}5039 + 0{,}273\ CO_2)\ [kg /100km]$$

Solving the equation towards CO_2

$$CO2_{Petrol} = (FC_{Petrol} / 0{,}118 -0{,}5138) / 0{,}273$$

$$CO2_{Gas} = (FC_{Gas} / 0{,}1336 -0{,}5039) / 0{,}273$$

Total CO_2 of both burned fuels

$$CO2_{Total} = CO2_{Petrol} + CO2_{Gas}$$

$$= [(FC_{Petrol} / 0{,}118 + FC_{Gas} / 0{,}1336 -0{,}5039)] / 0{,}273$$

Where the summand " – 0,5039 ", which is coming out of the unburned HC + CO amount is considered only once – for simplification assigned to the CNG fraction.

Using the M_{Petrol} and M_{Gas} from the control unit in the Unit [g] reconverted to [kg] and assigned to the Distance of the driving cycle will lead to

$$CO2_{Total} = [(M_{Petrol} * 100 / 1000 / Dist / 0{,}118 + M_{Gas} * 100 / 1000 / Dist / 0{,}1336 -0{,}5039)] / 0{,}273$$

$$CO2_{Total} = [(M_{Petrol}\ [g] / Dist\ [km] / 1{,}18 + M_{Gas}\ [g] / Dist\ [km] / 1{,}336 -0{,}5039)] / 0{,}273$$

CO2 in the Unit g/km

That means, using the M_{Petrol} and M_{Gas} from the control unit the CO_2 amount can be calculated and compared to the bag values from the emission test.

From figure 3 it can be seen, that the M_{Petrol} increase will lead to an increase of the CO_2. Assuming a NG consumption of 5kg/100km and the same energy consumption in NG and petrol operation, the CO2 emission increases by 0,4144g for each % replacement of NG by petrol. With the above described CO_2 calculation the values out of the control unit can be verified by entering the data in the $CO2_{Total}$ equation and comparing it with the bag values from the emission test. A deviation of +/- 10% on the petrol / gas share will lead to an error of +/- 2% in the CO2.

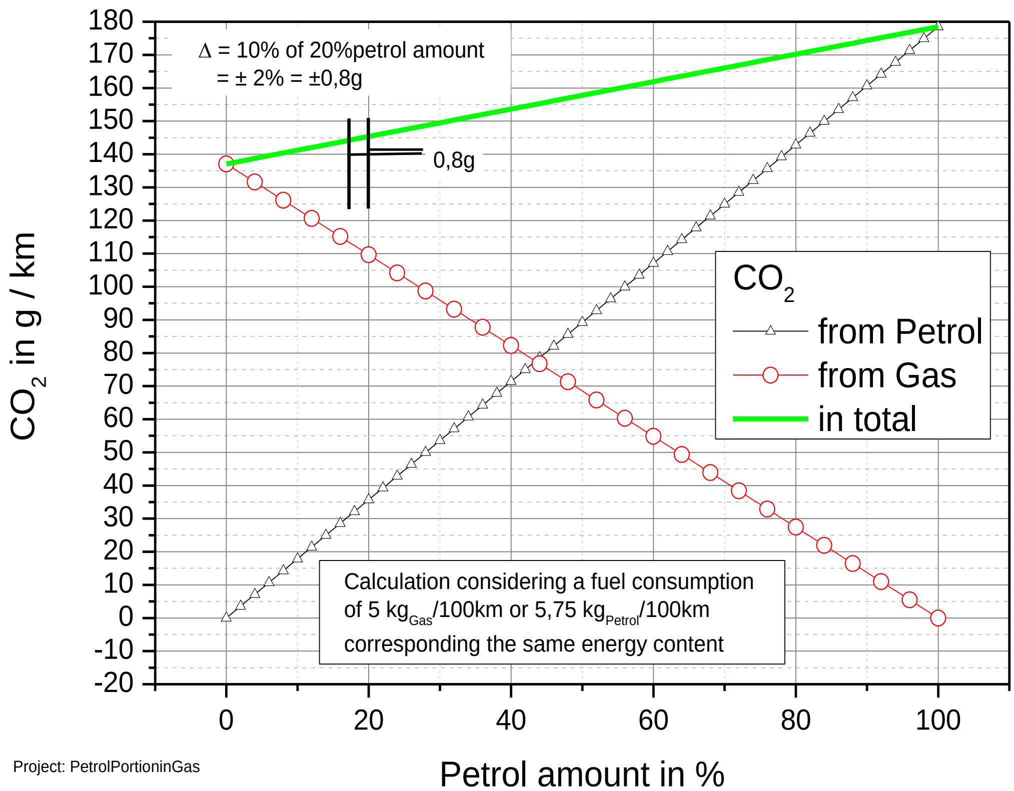

Figure 3: Calculated CO_2 dependent on petrol fuel amount

Considered cases

Two separate fuel tank vehicle type	Possible fuel/s in use at a time during ECE+EUDC cycle test				
	First fuel (liquid)	Second fuel (gas) (*)	Both fuels	Retrofit considered?	Who must support new PID?
Monofuel (gas)	yes (<15 l-tank)	yes	no *	no	Original ECM
Bifuel	yes	yes	no *	yes	Retrofit ECM2
Mixed-fuel (§)	yes	yes	yes	yes	Retrofit ECM2
Dual-fuel	yes (pilot fuel)	no	yes	no	Original ECM
Fuel to be used during tests	Yes, except Monofuel vehicle type	Yes, except mixed and dual fuel vehicle types	Yes, except Monofuel and Bifuel vehicle types		

(*) first fuel usage for starting and/or with current time limit not to be considered.
(§) using only the first fuel or a combination single and mixed fuel phases, during the cycle.

- The proposed method can also be used for Retrofit-systems as they must support OBD-requirements, too. Either the retrofit ECU communicates with scan tools according to SAE J1979 or the original ECM is modified (re-programmed) to do so.

Proposal for amendment ECE/TRANS/WP29/GRPE/201

Par. 3.2.5. of Annex 12, amend to read:

3.2.5 Without prejudice to paragraph 6.4.1.3. of Annex 4a, during the Type I test it is permissible to use petrol only or simultaneously with gas when operating in gas mode provided that the energy consumption of gas is higher than 80 % of the total amount of energy consumed during the test. This percentage shall be calculated in accordance with the method set out in Appendix 1 (LPG) or Appendix 2 (NG/biomethane) or Appendix 3 (LPG/NG/biomethane) of this Annex.

Annex 12, add new appendix to read :

Appendix 3

Bi-fuel gas vehicle - Calculation of energy ratio using control unit data

The determination of the fuel consumption of gas (LPG or NG/biomethane) and petrol is performed by the installed Engine Control Unit or the additional connected Gas Control Unit (GCU) by transmitting the integrated injected fuel masses via a PID to a Generic Scan tool according to SAE J1979 / ISO 15031-5 . The output is M_{Petrol} and M_{Gas} .

Procedure

- **The integral engine fuel consumption as M_{Petrol} and M_{Gas} is calculated since engine start in a resolution of 2 Byte, 0 …FFFF = 0 … 32769 g and a resolution of 0,5 g = 500 mg.**
- **The ECU internal resolution of FC accumulation shall be as high as the injection output in order not to miss any injected fuel quantity.**
- **The accuracy of the ECU determined fuel consumption must be better then 3 %**
- **The update rate for M_{Petrol} and M_{Gas} send to the scan tool is <=1 s.**
- **The integral fuel consumption is reset at engine speed = 0 rpm and ignition key- on.**

The calculation of the LPG energy ratio or the NG/biomethane energy ratio is performed as in Appendix 1 or 2 of this Annex using M_{Gas} from the control unit.