AEGPL amendments proposals to Regulations n. 83 and 115
Bi-fuel vehicles – New definition and provisions

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LPG EXCEPTIONAL ENERGY

AEGPL EUROPE

Objectives

The proposed amendments are aimed at redefining the class of bi-fuel vehicles to permit the simultaneous use of gas and petrol, even if limited in amount or duration.
These modifications are needed primarily for the approval of some bi-fuel vehicle equipped with petrol direct injection systems and retrofit systems intended to be fitted on vehicles equipped with petrol direct injection systems: 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.

To this end, are introduced:

1. modifications to bi-fuel vehicles definitions;

2. new requirements to set a minimum limit to gas energy ratio (used as inverse index of petrol use);

3. a method to calculate the gas energy ratio;

Bi-fuel vehicles
Definition and new requirements

Definition
Main elements:

1. two separate fuel storage systems
2. designed to run on only one fuel at a time.
3. **the simultaneous use of both fuels is limited in amount or duration (new)**

New requirements
Combined application of the following restrictions:

1. 60 seconds max limit applied to petrol warm-up period;
2. Gas energy ratio higher than 80% as calculated over the entire driving cycle;

Note: the choice of a min gas limit instead of a max petrol limit is motivated by the fact that petrol consumption is very low and, furthermore, this would be difficult to be measured with simple instruments.

Emissions

- No need to adapt measurement methods and correction factors for calculation of NOx and CO emissions as they are "essentially" fuel-independent (error on corrected concentration due to different DF's is negligible and conservative)
- THC emission calculation are "more" fuel-dependent due to the different density of the pollutants, but the assumption that only LPG is burned during the cycle (as it stands now – warm-up on petrol) is a conservative condition.

Emissions
THC calculation

EXAMPLE
Data
Ambient conditions:
ambient temperature: 23 °C = 297.2 K,
barometric pressure: PB = 101.33 kPa,
relative humidity: Ra = 60 per cent,
saturation vapour pressure: Pd = 2.81 kPa of H_2O at 23 °C.

Volume measured and reduced to standard conditions (para. 1.)
V = 51.961 m^3

Analyser readings:

	Diluted exhaust sample *(Ce)*	**Dilution-air sample** *(Cd)*
HC (1)	92 ppm	3.0 ppm
CO	470 ppm	0 ppm
NOx	70 ppm	0 ppm
CO_2	1.6 per cent by volume	0.03 per cent by volume

(1) in ppm carbon equivalent

Emissions
THC calculation

Given that:

$$DF = \frac{13.4}{C_{CO2} + (C_{HC} + C_{CO}) \cdot 10^{-4}}$$ for petrol

$$DF = \frac{11.9}{C_{CO2} + (C_{HC} + C_{CO}) \cdot 10^{-4}}$$ for LPG

$$DF = \frac{9.5}{C_{CO2} + (C_{HC} + C_{CO}) \cdot 10^{-4}}$$ for CNG

DF's differs in percentage terms by the following:

ΔDF% (LPG – Petrol) = -11.2%

ΔDF% (CNG – Petrol) = -29.1%

Calculating for all fuels the corrected concentration of HC in the sampling bag:

$$Ci = Ce - Cd \left(1 - \frac{1}{DF}\right)$$

Ci = 89.371 for petrol
Ci = 89.418 for LPG
Ci = 89.558 for CNG

so, in percentage terms, the differences, in relation to petrol, are:

ΔCi **% (LPG-petrol) = +0.053%**

ΔCi **% (CNG-petrol) = +0.209%**

Percentage error is positive but negligible

Emissions
THC calculation

Given that:

$M_{HC} = C_i * V_{mix} * Q_{HC}$

Differences in DF's do not weigh significantly in final calculation.

Q_{HC}'s are, instead, influential:

QHC = 0.631	for petrol
QHC = 0.649	for LPG
QHC = 0.714	for NG

In conclusion, considering **the cycle fully driven on gas**, the mass emissions per km will be higher with respect to **the limit case** (20%petrol, 80%gas):

ΔM_{HC}%(LPG-limit)= + 0,57%

ΔM_{HC}%(CNG-limit)= + 2,42%

Energy gas ratio - Calculation method

Measurement of gas mass consumed during the cycle:

- fuel weighing system measuring the weight of the LPG storage container during the test:
  - accuracy of ± 2 per cent of the difference between the readings at the beginning and at the end of the test or better
  - careful installation of the device according to the instrument manufacturers' recommendations and to good engineering practice to avoid measurement errors;

- other measurement methods are permitted if an equivalent accuracy can be demonstrated;

Note: with particular reference to mass flow metering, the reliability of such type of instrument – on gas - seems not proven yet in transient conditions and, furthermore, its positioning and installation, in a bench test, might raise some problems, likely affecting reproducibility of the measurement method

Energy gas ratio - Calculation method

Formula demonstration

$\mathbf{G_{gas} = E_{gas}/E_{tot}}$ (1) where: $\mathbf{E_{gas} = m_{gas} * H_{gas}}$ **(2)**

$\mathbf{E_{tot}}$ is the total energy required for type 1 test (MJ)
$\mathbf{E_{gas}}$ is the amount of energy supplied by gas fuel (MJ)
$\mathbf{m_{gas}}$ is the mass of gas burned during the type 1 test (kg) which supplies E_{gas}
$\mathbf{H_{gas}}$ is the specific heating value of gas (MJ/kg).

The total energy used during the type I test can be derived from fuel consumption data, assuming that only gas is burned during the test:

$\mathbf{E_{tot} = m_{tot} * H_{gas}}$ **(3)**

$\mathbf{m}_{tot}$ is the total mass of gas derived from fuel consumption data (kg)
$\mathbf{H_{gas}}$ is the specific heating value of gas (MJ/kg).

Energy gas ratio - Calculation method

The total mass (expressed in kg) can be derived from the mean fuel consumption of R101 (expressed in l/100km) by the following equation:

$$m_{tot} = FC*d*dist/100 \qquad (4)$$

FC is the fuel consumption calculated according to Annex 6 of Regulation 101 (l/100km)

d is the density of gas (LPG: 0.538 kg/l, CNG: 0,654 kg/m3, see par. 5.2.4. of regulation 101)

dist is the total distance travelled during the type 1 test (km)

Substituting eq. 4 into 3, and then eqs. 3 and 2 into 1 the result becomes:

$$G_{gas} = m_{gas}*100/(FC*dist*d) \qquad (5)$$

Energy gas ratio - Calculation method

FC as calculated on LPG only is a conservative assumption:

	LPG	**Petrol**				**LPG**	**Petrol**	
Energy consumption	80%	20%			Energy density	24,748	32,25	MJ/liter
Liter consumption	84%	16%			Energy density	46	43	MJ/kg
Mass consumption	79%	21%			Density	0,538	0,75	kg/liter
Mass ratio CO2/fuel	3,00	3,17						
CO2 contribution	78%	22%						
	Real	**LPG only**	**Delta%**			**Energy density**		
Liter consumption by CO2 formula [l/km/1gCO2] (1)	0,057	0,061	7%		**Real**	25,96	MJ/liter	
Energy consumption [MJ/km/1gCO2]	1,488	1,520	2%					
Energy ratio	0,672	0,658						
Difference		-2,11%						
(1) : CO and HC factors negligible								